MONOGRAPHS ON TEA PRODUCTION IN CEYLON

No. 2

THE COMMONER DISEASES OF TEA

TEA RESEARCH INSTITUTE OF CEYLON
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PREFACE.

FOR administrative purposes the work of an agricultural station such as the Tea Research Institute is divided into sections, of which one is the Division of Pathology. That in turn is subdivided into two parts, the Entomology and Mycology sections. By that nomenclature, entomology is stretched to include the study of animals with eight legs in addition to those with six, and mycology becomes all embracing and takes under its wing not only the fungi but every other agent associated with disease. This apparent division of work is quite artificial as no section can work efficiently without overlapping and co-operating with other divisions. Insects, being one of the greatest enemies of man, not only of himself personally but of his domestic animals, crops and goods, merit separate consideration, and for that reason, no mention of them will be found in this account of tea pathology. It deals with such subjects as fall to the lot of the mycology division.

The rational treatment of any plant disease depends upon a knowledge of its cause, and of the way it affects the plant's vital processes. Such knowledge is probably of more importance to the tea planter than to other agriculturists because of the nature of his crop and methods of harvesting. Control of disease in tea is largely a matter of bush management; spray formulae and schedules find little place in it.

As this account is intended primarily for the young tea planter, I have not assumed that he has any greater knowledge of plant physiology than of plant pathology. The two subjects are not easily separable, and it is quite impossible to understand a pathological condition without a knowledge of the plant in health, its requirements and the functions of its parts. I have, therefore, attempted to give a simple account of disease, why it occurs, rather than detailed descriptions of symptoms and methods of treatment. Simplification is often accompanied by unintended distortion of the truth due to too broad generalisations. Some statements will probably not obtain the unqualified approval of experts, and there are view points other than those presented here. Natural selection is not the only theory of evolution, and physiological processes are never quite as simple as they are pictured here.

The first step towards efficient control of any disease is the accurate diagnosis of its cause. It is not intended that the planter

with the aid of such descriptions as are given here will be enabled to diagnose all the diseases of the tea bush at sight. In cases of doubt, and there will be many, a plant pathologist's opinion should be sought. This information is intended to supplement the advisory work of the Institute, not to replace it. As diseases cannot be divided easily into the categories given as chapter headings, an index is attached to allow easy reference.

At the end of each chapter there is a short literature list. References are limited entirely to the Institute's publications which are available to all Ceylon tea planters. More technical papers are not cited, though many are to be found in the appropriate technical journals.

Finally, I wish to acknowledge with grateful thanks the co-operation and assistance extended to me over many years by my colleagues on the staff, both senior and junior, past and present, and to the many planters with whom I have discussed pathological problems. In particular, I would mention Mr. C. A. Loos who has been my personal assistant for many years and with whom it has been a pleasure to work. The photographs (except those shown as Plate 5) and line drawings which illustrate the text are his works; and as I left Ceylon before the manuscript went to press I am indebted to him for arranging the plates and seeing the work through to publication. To him and to Mr. S. N. Vander Wal for his work with the Index I tender my thanks. The photographs shown as Plate 5 were taken by Mr. L. S. Bertus of the Department of Agriculture and my thanks are due to him and to the Director of Agriculture for permission to use that block.

CHAPTER 1.

INTRODUCTION.

'Health' and 'disease' are words in common usage but neither is easy to define. The conditions they denote are opposites. A healthy individual is one free from disease, and a disease is something adverse to health. What then must be regarded as a disease of tea ?

The struggle for existence among living organisms is a struggle between opposing forces. On the one side is an inherent force, within the organism, tending to exhibit itself through normal development to full maturity and the propagation of its kind ; and, on the other, the adverse factors of the environment which tend to suppress that development. If we regard the display of the inherent force, complete normal development and full maturity, as indicative of health, then the suppressive factors of the environment must be the elements oi disease.

Such a definition would imply that the grasses in an ungrazed pasture, growing normally and unhindered, are healthy, but as soon as the pasture is grazed and the plants are prevented from reaching maturity, these same grasses are diseased. That is not a normal meaning of the word ; yet, if too many cattle are grazed continuously on that pasture, the grasses die. The deaths are then usually attributed to mismanagement, not to disease. But is there any real difference ? Leaves are removed from a tea bush as harvest, and if too many leaves are removed as by continuously stripping, death will result. Again. that may be ascribed to mismanagement. But if the continued stripping is caused not by man but by another organism such as a fungus, the death would certainly be attributed to disease. The results are the same yet one is termed mismanagement and the other, disease.

It would appear, therefore, that only certain adverse factors in the environment are regarded as disease-causing elements. Thus, we speak of fungus, bacterial, virus or environmental diseases, but when the ravages are caused by insects, we speak of pests, and if the ravager is man, mismanagement becomes an appropriate term. That is one point of view ; to the bush it cannot be material whether the damage is caused by fungi, insects or man, so long as the consequences are the same.

All animals are dependent upon green plants either directly or indirectly for their food. Without green plants, animal life would be impossible. Consequently every species of plant is used by some animal (including insects) as a source of food. Some plants, particularly fungi, have no chlorophyll (the colouring matter of green plants) and are therefore incapable of making their own food, and must obtain it directly or indirectly already prepared by plants. In this respect they resemble animals. Like insects, those fungi which feed on living plants often prefer specific hosts. Some will feed on one species only whereas others are capable of getting their requirements from many. Though animals and parasitic plants attack living things for the same reason, to get food, and the damage done to a plant by a fungus may be no more than that caused by a voracious animal, the former injury is usually termed disease but the latter is not. The distinction is obviously artificial.

A view concerning plant health and disease, one which gains more credence amongst laymen than amongst pathologists, has been expressed as follows :—"Insects and fungi are not the real cause of plant diseases and only attack unsuitable varieties or crops improperly grown. Their true role in agriculture is that of censors for pointing out the crops which are improperly nourished. Disease resistance seems to be the natural reward of healthy and well nourished protoplasm" This view implies that a healthy plant is one which is not only free from disease at the moment, but one which will resist all diseases, and upon which even insects will not feed. One might well ask "Does a healthy plant as so defined exist anywhere ?" If not, then also by definition, no plant is perfectly nourished. The definition implies that an agriculturist's best method of protecting his crop is, or should be, merely a matter of its proper nutrition. Proper nutrition is certainly essential for health, but it should not be assumed that good health affords protection against disease. Few healthy people would rely on their health alone to safeguard them against the consequences of a bite from a rabid dog. Nor will good health protect plants against insects or other parasites. Any idea that plants can be fully protected by proper nutrition, by the putting of something into the soil, be it compost or anything else, is but wishful thinking.

Health, no matter how it is defined, is largely a matter of environment. Under perfect conditions, i.e., in an environment which contains no factor which will repress normal development to full maturity, the organism, be it animal or plant, will be healthy. But perfection is rarely achieved. An environment made up of so many different factors is sure to contain one or more which will

repress to some extent the normal growth of the organism within it. The factor may be purely physical — too high or too low a temperature, too little or too much water, the absence of some essential food material, or it may be organic — the presence of parasitic or predatory organisms. Whatever we call such adverse factors, whether we class them all as disease-causing elements or prefer to name some as pests or mismanagement, their action must be countered if truly healthy plants are to be maintained.

Methods for plant protection are based on a knowledge of the environmental factors which operate to the plants' detriment. That study and the devising of means of protection are work for specialists. But if such methods are to be applied rationally the planter must have some knowledge of the why and wherefore of them. He will then be able to make such modifications as may be necessary to suit varying circumstances.

Where plant diseases are concerned, emphasis is always placed on protection, not cure. Animals may be cured of most diseases including many of those resulting from invasion by parasites. The cure is effected mainly by the animal itself, largely because of particular powers of its blood. A doctor may assist his patient in various ways, but the important factor in achieving a cure lies in the patient himself. A plant has no blood and nothing with the blood's curative powers. Perhaps that is because of another great difference between animals and plants. Any damage caused to any organ of an animal's body must be repaired else that organ is permanently impaired; it cannot be replaced. Plant organs can be replaced, but not repaired. So a plant replaces whereas an animal repairs.

There is another difference between many animals and plants and that is the value we place on their lives. When a domestic animal acquires an infectious disease, it will be given the chance of curing itself with some external help, if other animals can be safeguarded against infection. But when the disease is known from experience to be incurable, or the probability of other animals becoming infected is great, the animal is destroyed as soon as the disease is recognised. In some instances the law insists on that. Plants cannot conveniently be isolated, their value is relatively small, and the risk of infection spreading to other plants is great. So the treatment of many plant diseases can be summed up in the words 'cut and burn.' The 'cut' is to assist the plant to get rid of an infected organ, such as a branch, which it cannot shed for itself, and the 'burn' is to destroy the parasite within that organ or plant to prevent it producing and disseminating its spores. Such

treatment applies to infectious diseases only, of which there are many, though all are not of equal importance.

The tea planter owing to the nature of his crop is prevented from using some of the most efficient methods of plant protection and must rely largely on sound agricultural practices. It is hoped that in what follows the planter will find some things of interest which in the continuous fight against disease may help him to realise the different ways his agricultural methods influence the incidence of disease.

LITERATURE.

Gadd, C. H. Compost and disease.—*Tea Quarterly*, **10**, 93-100 (1937).

— Life and death.—*Tea Quarterly*, **18**, 101-106 (1947).

CHAPTER 2.

NUTRIENT ELEMENTS.

For many years botanists believed, because they could demonstrate the fact by experiment, that green plants such as the tea bush require onlv ten elements for normal healthy growth, namely, carbon, hydrogen, oxygen, nitrogen, sulphur, potassium, calcium, magnesium, phosphorus and iron. Of these, carbon is obtained from the air and the others from the soil — hydrogen and oxygen as water. The exclusion of any of these elements leads to a check in development and finally to death of the plant. Modern research has shown that the above list is incomplete and that other elements such as boron, manganese, copper and zinc are equally essential. In all probability the list is still incomplete.

How came it that the earlier research workers made the mistakc regarding these extra elements? The answer is relatively simple. Though essential, they are required in such minute quantities that sufficient was present as impurities in the workers' 'pure' chemicals, distilled water or even his specially clean glass-ware. When only very small quantities are essential the elements are usually referred to as "micro-nutrients," "trace elements" or "minor elements." It should be noted that the term 'minor' does not refer to importance but to quantity.

The planter will realise that of the elements listed above, he knowingly supplies only three of them to his bushes, viz. nitrogen phosphorus and potash. The others normally occur in sufficient quantities in the soil. But when the bushes are unable to get sufficient of one of them, either because it is absent from the soil or because it occurs in a form unavailable to the bush, its lack will be exhibited in some form or other, by paucity of growth and other specific symptoms.

A belief that disease is due mainly, if not entirely, to malnutrition may induce a planter to experiment with one or more micronutrients in an attempt to ameliorate the growth of his bushes If so, he will be well advised to consult a specialist before taking any action, otherwise he runs the risk of causing severe, though unexpected, damage. Also, the provision of the micro-nutrient,

though normally obtained from the soil by roots, may not be merely the simple matter of adding the supposedly deficient element to the soil. For instance, iron, one of the micro-nutrients, occurs in almost all soils, yet plants growing on particular soils may have a characteristic chlorotic appearance — the leaves are yellowish due to deficient development of the normal green colouring matter, chlorophyll — symptomatic of iron deficiency. The soil is most probably not deficient in iron though some plants growing on it are unable to get sufficient for their needs. The presence of large quantities of lime will cause the iron to assume a form in which it cannot be absorbed. This disease is well known (but not in tea) as iron chlorosis. or by a more descriptive name "lime induced chlorosis." The addition of more iron to the soil will not ameliorate the condition because the added iron will quickly be transformed into the same unavailable form. To ensure that the plant gets the iron it has to be injected, or supplied in ways other than via the soil and roots.

Two diseases of tea have been reported to result from deficiencies of essential nutrients normally obtained from soil. One is due to a deficiency of potash, and the other of sulphur. Neither is known to occur in Ceylon. The *potash* deficiency disease was reported from Java and its symptoms are similar to those occurring in other plants suffering a similar shortage. The bushes develop poorly and the leaves have a characteristic "scorched" appearance. *Sulphur* deficiency is somewhat unusual, but it has been reported from Africa as the cause of a disease of tea. It is known as Tea Yellows, as the leaves at first are mottled with yellow. Later they are dwarfed. The final state is a leafless bush bearing many dead and dying thin shoots. Both diseases are curable by suitable provision of the deficient element.

The element *copper* may be of particular interest to tea planters because it is an essential ingredient of the enzyme which causes the fermentation of green leaf in the factory. The leaf from some bushes ferments more rapidly than that from others. There is a good deal of variation amongst bushes in this respect. One bush on St. Coombs, whose leaf hardly ferments at all, has received a good deal of attention. It has been propagated vegetatively and so is now grown in different places, yet invariably the leaf fails to ferment properly though surrounding bushes are normal in this respect. Is it diseased? The original bush and all those derived from it grow vigorously, and their development is on the whole rather better than the average. Obviously it cannot be suffering from copper deficiency else its growth would be impaired. The

evidence shows that the soil is not deficient in copper and that the bush takes up sufficient for its vital needs. The only comment necessary is that the failure of leaf to ferment normally in the factory cannot be interpreted as indicative of a failure of the bushes to obtain sufficient copper for their needs. More probably, as is the case with the St. Coombs bush, it is due to an inherent disability to make that enzyme efficiently or in sufficient quantity. Whatever function that enzyme may serve in the bush, it cannot be quite the same as that demanded of it in the factory.

Carbon is the one nutrient element obtained from the air, and for that reason, if no other, is worthy of special mention. It cannot be said to be of greater importance than other essential elements, but it is required in much greater quantity; forty percent of the harvest is carbon.

Carbon is obtained by all green plants from the relatively small amount of carbon dioxide in the atmosphere. Carbon dioxide is the gas exhaled during respiration and liberated from organic materials such as wood and coal, when burnt. It enters the leaf as a gas and there undergoes a profound change. The carbon becomes united with hydrogen and oxygen, from water, and with some of the nutrient elements, (such as nitrogen, phosphorus and sulphur) absorbed by the roots, to form complex organic compounds, carbohydrates, proteins and oils, well known as animal foods. One of the simplest of these is the carbohydrate, sugar. This consists of the elements carbon, hydrogen and oxygen in certain proportions, but in addition, locked within it, is a considerable quantity of energy derived from sunlight. That energy is released when the sugar is broken down to simpler compounds which can be done quite rapidly by burning it. Then the energy is released as heat. It is this readily available energy which makes the real difference between nutrient elements and true foods. All living organisms, animal and plant, require that energy and it is as essential to them as are the material elements of the food.

The actual processes of manufacture (photosynthesis) taking place within green leaves need not be followed in detail. As yet they cannot be duplicated in a chemist's laboratory. When that is achieved many of the world's food problems will be solved.

From this brief account of plant nutrition it will be evident that certain mineral elements are essential. Equally essential are leaves, where elaboration takes place, and sunlight, which provides the energy used and stored during manufacture. The importance of leaves and sunlight is apt to be overlooked at times when

plant nutrition is discussed. At one time, manures were applied around tea bushes very soon after pruning with the object of helping the bushes to refoliate. The fact that bushes without leaves could make no use whatever of the extra nutrients supplied was overlooked.

It is of course equally true that a bush cannot grow healthily, even when leaves are present, if one or more of the essential elements are deficient. The insufficiency of any one essential element will cause disease, and the nature of the symptom will depend upon the function that element fulfils in the bush's economy.

LITERATURE.

Bond, T. E. T. Potash deficiency in tea cultivation (Review) *Tea Quarterly,* **13,** 139-145 (1940).

— Deficiency diseases and the role of 'minor elements' in plant life.—*Tea Quarterly,* **16,** 9-15 (1943).

Eden, T. Potash deficiency in tea cultivation in relation to Ceylon conditions, *Tea Quarterly,* **13,** 146-147 (1940).

Gadd, C. H. A sulphur deficiency disease of the tea bush (Review).—*Tea Quarterly,* **6,** 121-127 (1933).

Hoagland, D. R. Minute amounts of chemical elements in relation to plant growth.—*Tea Quarterly,* **13,** 148-152 (1940).

CHAPTER 3.

STARVATION.

A tea seed consists of a germ (the embryonic root and stem) and a mass of food, consisting of carbohydrates, proteins and oil. As the young plant grows, the seed gradually shrivels as the food is consumed. When the plant has a few leaves it becomes independent, and the remains of the seed can be removed without causing much harm. But if in addition, the young leaves are removed, death will result no matter how well the plant may be supplied with essential mineral nutrients. Death would be due to starvation following maltreatment.

Amongst young tea seedlings, plants with white or yellowish leaves are sometimes seen. Such plants at first grow as well as their green companions, but later, growth gradually ceases and death ensues. The time of death synchronises with the exhaustion of the food supply in the seed. The white or yellowish leaves do not contain the essential green colouring matter, chlorophyll, and therefore are incapable of manufacturing food. This condition is not due to any adverse factor in the environment and cannot be corrected. So the abnormal plants die of starvation resulting from as inherent disability.

Inherent factors leading to abnormal growth, malformation and sometimes death occur in both animals and plants. In plants such abnormalities are known as 'freaks' or 'sports,' names which distinguish the condition from disease induced by adverse environmental factors. Abnormalities are not all harmful, as many horticultural varieties have arisen as 'sports.'

The food elaborated in the leaves is required by all the living cells particularly where growth occurs. It is transported in a soluble form along special channels, termed *Phloem,* situated in the bark or cortex, the softer tissue which surrounds the woody cylinder, and which often can easily be peeled off both stems and roots. Water with essential mineral nutrients dissolved in it, flowing from the roots to the leaves, passes through the wood. At times more food is elaborated than is required for immediate use. The excess is then stored in various parts for use as required later. Some reserves are converted to insoluble forms and so immobilised

for storage. For instance, carbohydrate transported as sugar, is immobilised as starch on storage; it has to be reconverted when required for use later.

The tea bush stores its reserves in the roots, which perhaps is fortunate as little is lost when branches are pruned. The presence of starch reserves in tea roots may easily be demonstrated. When a solution of iodine (such as is used for medical purposes) is applied to a cut surface of a tea root — the cut should preferably be made transversely — the presence of starch is indicated by a dark blue or black colouration. In the absence of starch the cut surface stains yellow (Plate 1, Figs. 3-6). Sections through roots with or without starch in them are shown in Plate 1, Figs. 5 and 6. In Fig. 6 the starch grains can be seen within the cells. Iodine strains the grains dark blue, making the cut surface appear black, whereas when the cells contain no starch the yellowed cell walls only are seen.

The amount of food in reserve fluctuates somewhat from time to time. Deciduous trees which drop all their leaves annually must draw upon their food reserves in spring in order to form a new canopy of leaves. The tea bush, however, is evergreen and does not require a reserve for this purpose. But like other organisms it strives to reproduce its kind, and so stores food preparatory to its transference to seeds. As pruning tends to prevent flowering and fruiting, the reserves stored for seed production can be utilised for refoliation after pruning. Such reserves make clean pruning possible.

But all bushes are not all equally good hoarders, and climatic conditions have a marked effect on the amount of food put into store. Bushes grown up-country store far more than those growing at lower elevations. It may be that the warmer conditions, by stimulating more rapid and vigorous growth, cause more food to be used immediately, leaving smaller amounts for storage. Whatever the reasons, the fact remains that though up-country bushes normally have ample reserves, low-country bushes too frequently are deficient. Of course no hard and fast dividing line can be drawn, but for practical purposes it can be assumed that below 3,000 ft. a deficiency is likely to occur, and the lower the elevation the smaller is the reserve.

At one time many bushes died in the low-country after every pruning. Of this condition Petch, in his book "The diseases of the tea bush" (1923) wrote "At first, perhaps only a few bushes die and little notice is taken of it. At the next pruning the number is greater and attracts some attention, and the increase continues

with each pruning until fifty per cent of the bushes may be attacked. Four prunings may convert indifference into panic." At that time the disease was thought to be caused by the fungus *Botryodiplodia theobromae* (it has other names, including *Thyriadaria tarda)* and so was known as Diplodia disease. It is now known that neither that fungus, though it is sometimes found on the roots, nor any other is the cause of it. It should be noted that the disease occurs only after pruning, never when the bushes are in full leaf ; and the affected bushes are scattered haphazard through the fields, and are not in distinct groups as is usually the case when a root disease results from attacks by parasitic fungi.

The cause of the disease is a deficiency of food reserves at the time of pruning ; rational treatment can be based on that knowledge. It will be evident that if the bushes are clean pruned (Plate 1, Fig. 1) and so deprived of all foliage at a time when there is little or no elaborated food in reserve, the bushes will die and nothing can be done about it. The provision of manures cannot help. If the reserve is very small, insufficient to make a complete canopy of leaves, new growth will occur on a few branches only, and the rest of the frame will die.

A possible method of prevention is to rest the bushes for a short time before pruning. In practice, however, this method has not given satisfactory results and is not recommended except when for good reasons the bushes have to be clean pruned which should be a rare event.

The most rational method of prevention is to adopt types of pruning which ensure that sufficient foliage is left on the bush to enable it to elaborate enough food for immediate requirements. Two such pruning methods in common use are known as "Rimlung pruning" (Plate 1, Fig. 2) and "Cut-across." These forms of pruning have been tested by accurate experimentation and some of the results are given as Table I.

TABLE I.

Mortality per 1,500 tea bushes, growing at 200 ft. above sea level, after pruning.

Type of prune	Average No. of leaves per bush	No. of deaths
Clean prune ...	3.0	67
Cut-across (low) ...	41.6	27
Rim Lung ...	200.5	8

The above table is taken from an article by F. R. Tubbs in the *Tea Quarterly*, Vol. V, pp. 108-112 (1932). In the original publication some of the figures were transposed. The figures given above are correct.

The bushes were all pruned at a uniform level, that of the clean pruned bushes. The cut-across was therefore lower than is usual for that style of pruning, with the result that fewer leaves were left and the number of deaths was greater than usual. Because of this, the experiment demonstrates the importance of the number of leaves better than it otherwise might have done. It is clear that as more leaves are left on bushes the number of deaths decreases.

The general adoption of these and similar methods of pruning resulted in a marked reduction in the number of deaths after pruning. With the passage of time the reasons for the methods are sometimes forgotten ; bushes are clean pruned for a change, usually with dire results.

It should be clearly understood that such methods as Rim Lung pruning and Cut-across are not the best for all elevations. They are intended to prevent death from starvation following pruning where food reserves are likely to be deficient. The testing of roots to ascertain the status of food reserves in each bush before pruning is not practicable. As a general rule it may be assumed that bushes growing above 3,000 or 3,500 ft. may, without undue risk, be deprived of their leaves when pruned, but below that elevation the risk increases as the altitude decreases.

The same principles should apply to supplies. It is generally assumed that because a young plant has not been plucked it must therefore contain sufficient food reserves in its roots to allow of a pruning which removes all its leaves — the so-called 'centering.' Many deaths amongst low-country supplies are due to food deficiency at the time they are first cut back. If such deaths are to be avoided, the training of plants should begin at an earlier stage and in a manner that they are never made leafless.

The frequency of defoliation is another important matter. No matter how much food a bush may have in reserve it will ultimately be exhausted if called upon to make frequent refoliations owing to rapid succession of defoliations. This is one reason why leaf diseases often prove so disastrous.

Frequent defoliation is sometimes recommended as a means of destroying perennial weeds, The underlying idea is the same, the

PLATE 1.

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2

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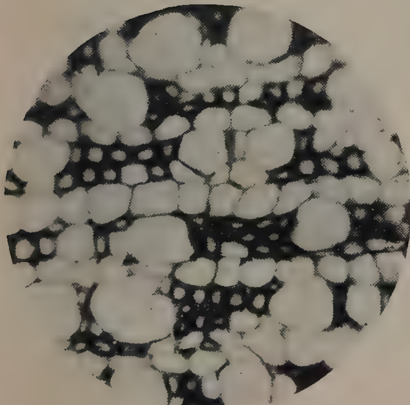

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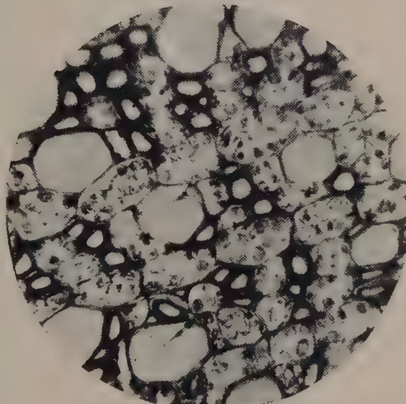


6

STARCH DEFICIENCY

1. Clean-pruned bush — Recovery unlikely if the bush *is* markedly deficient of starch.
2. "Rim-lung" pruned bush — note the presence of leaves to assist recovery.

3.—4. Iodine test on excised starch deficient (3) and healthy (4) tea roots.

5.—6. Microsections of roots showing absence (5) and presence (6) of starch grains.

exhaustion of food reserves by causing the plant to draw on them repeatedly for refoliation. The weeds must not be allowed the opportunity of making good the losses.

The harvest from tea bushes is its young leaf. Bushes in plucking are deprived continuously of young leaf and are thereby stimulated to produce more which in turn is removed. The amount of young leaf any bush can produce is dependent on the amount of food it can manufacture, i.e. upon its leaf area, and not upon the amount of nutrient elements supplied to its roots. The tea planter has a problem not usually encountered by other agriculturists. How much leaf should be harvested and how much should be left for the bush? From past experience a formula has been devised and is generally accepted as the standard of good plucking in Ceylon. It allows two leaves and a bud to be removed leaving one full leaf above the fish-leaf for the bush. In general it is an excellent rule but blind adherence to it under all circumstances does not constitute good management.

All cannot be well with a bush unless it carries a full canopy of leaves. Yet bushes with thin foliage are plucked as severely as those with a denser canopy. Often they are even more severely treated by the plucking cooly in her efforts to fill her basket. Over-cropping can only act to the detriment of the bush. Food reserves used for crop production cannot again be used when needed most, after pruning. Here then is one reason why deaths after pruning are more frequent at higher elevations than they used to be. The remedy should be evident.

Starvation may be brought about in another way, by a break in the channel along which the elaborated foods are conducted. The removal of a complete ring of bark from the main stem of a tree (known as ring-barking) makes a complete break in these channels, and so long as the break is maintained, the roots can receive no more food from the crown. The roots are then forced to live on such food as may be stored in them. So long as any remains, the roots function normally sending water and nutrient elements to the leaves. This is possible because the water channels lie in the wood which has not been damaged. But when the food is exhausted and the roots die of starvation no further supplies can be sent to the leaves. Then the crown dies, not of starvation but of a lack of water.

The break in the food channels may not result always from mechanical injury. The effect is the same if the tissues are killed but not removed, the elaborated foods cannot pass through the dead tissue. This kind of ringing sometimes occurs as the result

of attacks by parasitic fungi or by heat. Tea seedlings are seriously injured when the soil in which they are growing becomes overheated by the sun. Then a ring of tissue at ground level is killed and effect is exactly the same as when a ring of bark is removed. This condition is known as Collar rot of tea seedling (Plate 8, Fig. 3). Sometimes the damage occurs before the food in the seed is exhausted. Then, although the ringed stem dies, one or two new shoots arise from below ground, but whether they survive or not depends upon the amount of food available for their construction.

The importance of leaves and reserves of elaborated food cannot be too strongly emphasised. They are necessary for normal life and will assist a bush to recover from damage caused in various ways, by accident, by man or by parasites. But they do not give the bush any ability to resist specific parasites. A bush is just as liable to Poria root disease of Blister Blight no matter how much food may be in reserve. That reserve may be of value in restoring the damage caused by the latter disease but it will not save it from death from the former.

LITERATURE.

Gadd, C. H. A new view of the causation of Diplodia disease, *Tea Quarterly*, **1**, 89-93 (1928).

— The relationship between food reserves of the tea bush and disease. *Tea Quarterly*, **2**, 54-64 (1929).

— What is the Diplodia root disease of tea? *Tea Quarterly*, **3**, 44-48 (1930).

Tubbs, F. R. Some physiological aspects of pruning.—*Tea Quarterly*, **4**, 40-44 (1931).

— Recovery from pruning.—*Tea Quarterly*, **6**, 11-24 (1933).

— Resting the tea bush.—*Tea Quarterly*, **6**, 81-85 (1933).

CHAPTER 4.

WATER.

The tea bush like other green plants requires water in large quantities. An acre of tea in full leaf, during normal fine weather, will use about 10 tons of water per day, which is the equivalent of 0.1 inches of rain. Some is required for the making of food, the nutrient elements hydrogen and oxygen being obtained as water, but the greater part appears to be useless and is got rid of as water vapour from the leaves. This interpretation, however, is not strictly true as water also serves as a vehicle in which the essential nutrients and foods are transported as required, and in which waste products are carried away from the living cells.

The water absorbed by the roots contains small quantities of mineral salts dissolved in it. The solution is very weak, as it contains only about 0.05 to 0.2 per cent of dissolved substances. In order to obtain the requisite quantity of these the bush must absorb a large quantity of the solution and be able to get rid of the excess water. The rate of uptake is very largely controlled by the rate of loss, and so a balance between intake and loss is maintained. As the loss occurs almost entirely from leaves it will be evident that the uptake of a bush without leaves must be extremely small. For the same reason, bushes with few leaves absorb less water, and consequently less nutrients, than bushes with more leaves.

The only part of a root which can absorb water is a short region, white or cream in colour, just behind the root tip of the small hair-like roots, termed feeding roots. The other parts are protected by a corky layer which prevents water from entering or leaving. As the absorbing area of each root is small, their number has to be great in order that a bush may get the necessary amount of water. The large woody roots are valueless in this respect. Their functions are to stabilise the plant in the ground and to act as the channel along which water may pass from the feeding roots to the main stem and thence to the leaves. They are permanent, but the feeding roots are temporary and are replaced by others. As most nutrients, especially those added as manure, occur in the uppermost foot of soil, the feeding roots are almost entirely confined to that region.

A bush may be deprived of sufficient water in a variety of ways. There may be little or no water obtainable, as in times of drought; or existing water may be unobtainable because the feeding roots have been destroyed; or there may be a stoppage in the supply line between the absorbing roots and leaves. In all cases the above ground symptoms are similar. The first indication of water shortage is a wilting of the leaves; they become limp and tend to droop. This condition will be temporary after a hot dry day if the excessive loss can be made good during the night. A temporary wilt is more noticeable in many garden plants than in tea. If the loss cannot be made good, the wilt becomes permanent; the leaves become dry and brown and ultimately fall off the stems.

When the roots are damaged by parasites, deaths sometimes appear to be more prevalent during dry weather as though dry conditions favoured the disease. The reason is that so long as the water loss from the leaves is not very great, the impaired root system manages to supply sufficient water to prevent death, but when the loss increases because of the drier conditions, the roots are unable to obtain sufficient and symptoms of water shortage result.

Stoppages in the supply lines are usually due to injuries of the main roots or stems by parasites; such injuries may cause death of the whole bush or of a part only, depending upon the extent and position of the injury. As parasitic diseases will be described in more detail in later chapters, discussion here will be limited to shortages resulting from non-parasitic causes.

There is no simple way by which death from drought can be recognised with certainty in the absence of any information regarding climatic conditions. No known parasitic organism will be found on the roots and usually there will be evidence that the bush died while in full leaf. Frequently the fungus *Botryodiplodia theobromae* (and its accompanying white fringe around the extruded black spores) is to be seen on such roots. Petch observed that the fungus in this form is often seen on the roots when bushes which have been dead for a few weeks are dug up. With that the writer agrees, but he has seen it more frequently on bushes killed by drought than on those killed by starvation, and to him it invariably suggests drought as the cause of death.

Although plants in a nursery can be supplied with water during dry weather other measures have to be taken to ameliorate the condition of bushes in the field during times of drought. As regards watering, it will be sufficient to state that a good soaking of the soil at wider intervals is preferable to smaller quantities at shorter

intervals. Though water cannot be supplied to bushes in the field, measures can be taken to reduce water losses. As the water is lost from the leaves by evaporation (transpiration) the losses can be reduced by diminishing the evaporating area by removal of leaves, as by pruning or stripping. Bush green manures growing amongst the tea should also be lopped. The loppings and prunings should be left on the ground as a mulch to diminish water loss direct from the soil surface. No forking should be done at such times as that merely accelerates the loss from the soil.

A very unusual way in which water shortage may be caused is by the addition of excessive quantities of soluble manures to the soil. A few instances have occurred when labourers, engaged in distributing manure, have for unknown reasons buried the manure by the sackful between bushes. The result was that the leaves on the bushes on each side of the manure wilted, and some of their branches began to die. As the affected bushes occurred in pairs there was no great difficulty in locating the source of the trouble. But why should excess of soluble manure cause symptoms of water shortage ? Roots do not absorb water as blotting paper will. When placed in water or a very dilute solution roots will take up some of the water, but if the solution is strong the water moves in the opposite direction, from the roots into the stronger solution. The soluble manures formed too strong a solution which not only prevented the roots absorbing any, but actually withdrew water from them. As a matter of general interest it may be mentioned that soils (saline soils) are known in which the concentration of dissolved salts is so high that they are useless for normal agriculture though certain specialised plants can survive on them.

Too much water is as detrimental to the tea bush as too little. The tea bush prefers a well drained soil and cannot tolerate too much water about its roots. The roots, like other parts, require oxygen for respiratory purposes. This is obtained from the air which occupies the spaces between soil particles. When the spaces become filled with water the roots are deprived of oxygen and death results if the oxygen is withheld for a prolonged period. Death from this cause may often be diagnosed, in the absence of any information regarding field conditions, by a violet discoloration on the surface of the wood beneath the bark. Sometimes a particular fungus, *Sphaerostilbe repens* B. & Br., is found on roots killed by waterlogging, and its presence is a sure indication of an excessive quantity of water for tea.

Deaths from waterlogging of the soil or "wet feet" are probably more frequently encountered in nurseries than in the fields. Badly drained beds and overwatering are direct causes. Under

such conditions the growth of seedlings becomes stunted, and when the plants are pulled from the soil what remains of their roots is either rotted or appears to have been 'bitten off' by insects. Because of this appearance the disease is known as 'Bitten off.' (Plate 8, Fig. 1). Excess of water, however, is only one cause of that disease; another, more frequently encountered, has nothing to do with amount of water, but with the degree of soil acidity. Further reference will be made to it later.

LITERATURE.

Eden, T. The Soil as a water reservoir.—*Tea Quarterly*, **8**, 27-32 (1935).

Gadd, C. H. *Sphaerostilbe repens*.—*Tea Quarterly*, **1**, 16 (1928).

— Water and the plant.—*Tea Quarterly*, **8**, 20-27 (1935).

— Excess Manure.—*Bull. 19*, 28 (1939).

Tubbs, F. R. Drought and Pruning.—*Tea Quarterly*, **9**, 25-29 (1936).

CHAPTER 5.

SAPROPHYTES AND PARASITES.

An important difference between mineral and inorganic plant foods and true foods is the presence in the latter of energy which does not occur in the former. All living organisms require energy as well as materials with which to construct and repair their bodies, and the only form of energy they can use is that locked up in complex organic compounds. The energy is released as the compounds are destroyed or broken down to simpler substances. As living organisms can break down these complex substances, i.e. use them as food, they get both the energy and substance required.

When an animal feeds, the meal is transferred to the digestive tract, also known as the gut or alimentary canal. There, parts of it are made soluble by the action of specific digests, ferments or enzymes. The soluble parts are absorbed into the body proper and the insoluble material is evacuated as excreta. The lowest forms of animals and all plants have no digestive tract. Their meals have to be digested around rather than within themselves; then the phenomenon is termed decay, not digestion. Different organisms produce different ferments and so are able to digest (or decay) quite different types of material. For instance, few organisms can digest wood. To most it is valueless as food. But some species of fungi can feed on it and, by doing so, alter its texture to such an extent that the wood is recognised as rotted. What they leave as useless can be used by other organisms as food; and so the process goes on, each organism getting energy and substance from their different foods.

The destructive processes are relatively very slow, but they can be accelerated by combustion. When organic materials are burnt the energy escapes as heat; certain mineral elements are lost as gas, particularly carbon and nitrogen and others remain in the ash, which when returned to the soil can again be used by green plants. Carbon escapes as carbon dioxide which is the form in which green plants can use the carbon for synthesis. The construction and destruction of organic materials goes on simultaneously. Without the breaking down processes which we call decay, the earth would be littered to a great depth with fallen leaves, branches and dead bodies, in which would be locked up the elements essential for life.

Decay allows the same essential materials to be used over and over again, and kept in circulation. One element is apt to get out of the cycle when breakdown is excessive. That one is nitrogen which in its elemental gaseous form is useless to green plants except in exceptional circumstances. Its loss from the cycle is so great that at one time a scientist forecast a world famine because of it. His forecast was falsified by the ingenuity of scientists who discovered how to convert atmospheric nitrogen into a form usable by plants. Nitrogen now forms an important item in the manure bills.

Living organisms can be classified according to the nature of the materials they use as food. Those which feed only on dead material are termed *saprophytes*; others which can get some or all their food from living bodies are termed *parasites*. The great majority are saprophytes, incapable of taking anything directly from other living organisms. It is as though living organisms, both animals and plants, are encased in an invisible armour through which the saprophytes cannot penetrate but which disappears at death. From amongst the saprophytes certain organisms, the parasites, have evolved with an ability to penetrate that armour, particularly at weak places and so to get food unavailable to their saprophytic competitors.

Any advantage a parasite gains in that way is lost if and when it kills its host (the invaded organism) because with death the protective armour disappears. Yet many parasites do kill their hosts or the part they have entered, sometimes rather quickly. Then numerous saprophytes can get their food from the dead tissues. The presence of fungi and other organisms on a dead branch or root is, therefore, no proof that they killed it.

Parasites do not all have equal powers of penetrating the protective armour of living organisms; nor can they all penetrate the same type of armour. By this is meant that a parasite which can enter a living leaf may be incapable of entering a stem or root of the same kind of plant or of penetrating the leaves of plants of other species. Also, as organisms develop powers of parasitism they appear to lose in corresponding degree their ability to obtain food from dead materials. Some parasites, termed *obligate parasites* are unable to live on dead material. One such organism is *Exobasidium vexans* which causes Blister Blight of tea. That fungus does not immediately kill the part it enters; death follows in due course but not until the fungus has completed its life cycle and reproduced its kind. The majority of parasites which cause disease in tea kill the invaded part quickly, sometimes ahead of their own position. They then feed on the dead

tissues but must share the spoils with saprophytes. Such parasites are termed *facultative parasites* because they can live on either living or dead material.

What has been referred to as an invisible protective armour is more correctly known as Power of Resistance. All living things have that power and the fact that they become diseased, i.e. invaded by a parasite, is not because they have lost it but because some organism or other has acquired an ability to overcome a particular form of resistance. *Exobasidium vexans* may again be used to illustrate the point. That fungus can cause disease in very young leaves and stems of the tea bush but it cannot overcome the resistance of older tea leaves nor that of the leaves of any other plant yet known. Powers of resistance may be reduced by ill-health but such reduction is better known in animals than in plants. In animals too, resistance against specific diseases may be increased either naturally or artificially, but such acquired immunity is almost unknown in plants. As the ability of certain organisms to overcome particular forms of resistance in plants has gradually evolved, so is an increasing ability to resist those organisms evolving in plants. For instance, some tea bushes have very little resistance against *Exobasidium* and their leaves become blistered immediately conditions are favourable for the fungus, whereas other bushes have few or no blisters ever, no matter how much Blight surrounds them. The more susceptible bushes are not the weaklings, nor are the resistant bushes the more vigorous under normal conditions. The resistant bushes have an inherent power, expressed as resistance to that specific parasite. An individual plant, or variety of plant, which is particularly resistant against one parasite may be abnormally susceptible to another. Resistance in plants cannot therefore be merely a matter of health.

From the foregoing it will be evident that no simple explanation can be given of the specific nature of natural resistance which protects living plants against invasion by other organisms in search of food. The subject is obviously complex, but the evidence so far collected indicates that any idea of plants being given power of resistance against all parasites by some simple means possibly connected with nutrition is but wishful thinking.

Temporary protection can be given in various ways, the most efficient being by chemical means. This usually is in the form of substances known to be poisonous to the organism against which protection is sought. The poisons are sprayed or dusted on the plants at a time when the particular parasite is due to appear. The object is to kill it *before* it can enter the plant or do much damage.

The most useful poisons against fungi are sulphur and copper compounds, which can be obtained in convenient form ready for immediate application. Against insects there is a much longer list of suitable poisons.

The use of poisons on tea bushes in plucking must necessarily be avoided because of the danger of spray residues on the finished product. For that reason little will be said of spraying or dusting in what follows. It should be resorted to only in exceptional cases and then the greatest care must be exercised to prevent any poisoned material finding its way into the factory. Of course there is no objection to the use of chemical protection in nurseries and young areas where the leaf is not plucked for manufacture.

In general, it may be said that dusts are the more convenient for distribution, and though efficient against insects, they are less efficient than sprays against fungi. The reason for this is probably to be found in particle size. The immediate objective is to obtain as complete a coating of the insecticide or fungicide as possible so that no parasite can find lodgment on the sprayed or dusted surface without contacting the protective cover. Sprays are best applied by means of a machine which ejects the spray fluid as a very fine mist. Sufficient should be used to cover the plants but not so much as to cause drip.

The inability to make the fullest use of chemical protection deprives the tea planter of one of his strongest weapons in the fight against pests and diseases. Fortunately the tea bush has great powers of resistance and consequently is seriously damaged by relatively few insects and parasitic organisms. Otherwise, grown as it is, covering many square miles without any interruption, tea would not have survived without some form of chemical protection.

Before passing on to consideration of specific diseases and methods of control a short general account of one of the most important groups of plant parasites may be of interest. The fungi, of which several species cause disease in tea, are a group of primitive plants better known perhaps by such common names as moulds, mildews, mushrooms and toadstools. The fungus normally consists of thin threads which often form a tangled mass like cotton wool. The individual threads are termed *hyphae* and the mass, a *mycelium*. Sometimes the hyphae form very compact bodies like mushrooms or hard bracket-like objects sometimes seen projecting from decaying tree stumps. More usually the threads form a very loose mass so fine as to be almost invisible. They are all without chlorophyll and therefore cannot make their own foods as green plants do. Being plants they have no power of locomotion and cannot move

in search of food. They must grow where they fall as spores (seeds) and unless they fall on organic material suitable as food there is no possibility of their further growth. Their survival as species therefore depends largely upon an ability to produce spores in gigantic numbers to ensure that some at least will reach suitable food. For instance, *Exobasidium vexans* produces about one million or more spores per day from each white blister, but what the number may be in any field at a time when the disease is prevalent is beyond computation and probably beyond comprehension. All fungus spores are microscopic and are carried in the air as fine dust which slowly deposits everywhere. No wonder the fungi seem to appear from nowhere and their eradication is humanly impossible.

LITERATURE.

Gadd, C. H. Diseases in general and fungi in particular.—*Tea Quarterly*, **8**, 132-139 (1935).

Petch, T. The parasitism of tea root disease fungi.—*Tea Quarterly*, **1**, 10-15 (1928).

CHAPTER 6.

ROOT DISEASES.

The four commonest root diseases of tea in Ceylon are known by the names of *Poria, Rosellinia, Ustulina* and Brown Root. The first three are the generic names of the fungi which cause them; the last is a more descriptive common name. One objection to the use of generic names, as common names for fungus diseases, is that scientific names are sometimes changed for reasons not always appreciated by the layman.

The above ground symptoms of these and other root diseases are alike. They are always symptoms of water shortage, but they occur at times when the soil is not deficient of water. Their identification therefore depends largely upon recognition of the fungi associated with the plants and their invaded roots.

The easiest to recognise is probably Brown Root disease. The fungus which causes it is now known as *Fomes noxius* Corner; previously it was known as *Fomes lamaoensis* Murr and *Hymenochaete noxia Berk*. Its most prominent character is the crust of soil firmly attached to the roots and which cannot easily be knocked or washed off (Plate 3, Fig. 2). The mycelium of the fungus acts as a cement and can usually be seen as tawny brown threads forming small, somewhat wooly masses between soil particles, or dark brown velvety patches at the upper edge of the soil crust. The presence of a brown mycelium amongst the soil encrusting the diseased root distinguishes Brown Root disease from all others.

Poria or Red root disease is caused by the fungus *Poria hypolateritia* Berk, which is invariably to be seen on the surface of the diseased root. At first the mycelium is white, soft and somewhat fluffy but later it becomes compacted into smooth, thin, flat, dark-red cords or sheets (Plate 2, Fig. 4). These cords and sheets darken with age and are then not easily distinguishable from the root surface. Soil adheres to them, though not so firmly as to *Fomes noxius*, and this often makes their recognition difficult. The cords are white inside, and the smooth dark red casings are rather brittle. When some of the adhering soil is shaken off an infected root, parts of the outer casing are broken and the white interior is exposed;

PLATE 2.

1 2

ROOT DISEASES.

1. *Rosellinia arcuata* — mycelial stars beneath the bark.
2. *Poria hypolateritia* — mycelium on root.

this gives the root a speckled appearance. Estate coolies seem to recognise the disease most readily by this speckle. When the disease is well advanced, the wood is soft and watery; later it becomes a soft mush not easily extractable from the soil.

Rosellinia or Black root disease is most frequently caused by *Rosellinia arcuata* Petch. Another species of *Rosellinia,* viz. *R. bunoides* (B. & Br.) Sacc. having somewhat similar characters is sometimes encountered in the low-country tea, though rarely. The mycelium of *R. arcuata* is at first white, then smoky grey and finally black. On the surface of the root the mycelium forms black strands more or less woolly in appearance and easily distinguishable from old cords of *Poria.* When the bark is carefully separated from the wood small white stars of mycelium can usually be seen on the wood surface (Plate 2, Fig. 1). The characteristic black mycelial strands on the external surface and the small white stars beneath the bark make *Rosellinia arcuata* fairly easy to recognise. The white stars are not found under the bark of roots attacked by *R. bunoides.* Instead, small black points or narrow black strands are to be seen on the surface and embedded in the wood.

Ustulina or Charcoal Rot is caused by the fungus *Ustulina zonata** Lev. Roots attacked by this fungus have no visible mycelium on their surface. When the bark is removed, large white or brownish-white fan-shaped patches of mycelium are to be seen on the wood surface. The fans are often fused together to form a very thin continuous sheet, but the fan structure is usually recognisable. The wood is often traversed by black lines. Though many fungi can cause thin black lines in wood those of *Ustulina* can be recognised by their thickness and the frequency with which double lines occur, as though drawn with a faulty nib which makes two parallel lines simultaneously. The name "Charcoal Rot" is derived from the carbonaceous, brittle and charcoal-like nature of the fructifications which are often to be found at the collars or main stems of diseased bushes (Plate 3, Fig. 1).

In their mode of spread below ground *Ustulina zonata* and *Fomes noxius* are alike; they cannot pass from one root to another unless the roots are in close contact. *Poria* and *Rosellinia,* however, are able to grow freely through the soil, so the fungus growing on one root may reach another some distance away. This difference affects their distribution in the fields. *Poria* and *Rosellinia* diseases usually occur as patches whereas *Ustulina* and Brown Root diseases most frequently affect solitary bushes, usually situated near old tree stumps.

* Now known as *Ustulina deusta* (Fr.) Petrak.

That the felling of shade trees is often followed by root disease in the tea is well-known to all tea planters. A field of tea with a good stand of healthy shade trees such as Grevilleas or Albizzias may be free from any root disease until some of the shade trees are felled. One or two, or more years later tea bushes in the immediate vicinity of the stumps begin to die. The diseases concerned are almost invariably *Ustulina* and Brown Root disease; *Poria* and *Rosellinia* diseases rarely arise in that way.

Despite the large number of tea bushes killed annually by these four fungi they are in some respects rather weak parasites. Their spores are carried in the air and are finally deposited on the soil, on tea bushes and in every variety of places, yet the diseases they cause do not begin here and there indiscriminately in the fields nor are the diseases so prevalent as would be expected if spores directly caused infection. Evidently, the spores falling on the ground, on tea bushes or other living trees either fail to germinate, or having germinated are incapable of gaining entry parasitically into the tea bush on which they have fallen.

Both *Ustulina zonata* and *Fomes noxius* can obtain food from wood which they cause to decay. So, when their spores fall on the exposed wood surface of the stump of a felled tree they begin to grow and feed as saprophytes. No doubt they meet competition from other wood rotting fungi, but their condition is now very different from what it would have been had they not fallen upon suitable wood. In the microscopic spore there can be but a minute quantity of food but the tree stump provides an abundant supply. A small amount of food may not supply sufficient energy to enable the fungi to overcome the resistance of living cells, but with a large amount of food to draw upon they are able to exercise their parasitic ability to the full. If the tree was recently felled and the roots not yet dead their parasitic ability even though it be small enables them to forge ahead of their saprophytic rivals by entry into the still living parts of the roots. Also they can now pass from the stumps' roots to those of any tea bush in contact with them. In this way they keep ahead of their competitors for food.

It should be clearly understood that an abundant food supply does not give fungi any power of parasitism. Shortage rather than abundance of food would be the more likely to lead to evolution of ability to live parasitically. Parasitism is characteristic of definite species and is an inherent ability. If, as is often the case, the parasitic ability is small, the fungus, as it grows from the spore cannot exercise it until a larger supply of food, and consequently of energy, is obtained. A fungus growing on a "food base" (by which is meant

material containing suitable food) may be markedly parasitic whereas the same species dependent solely on the food within the spore may do little or no damage to a living plant.

For this reason many fungi are parasitic only if they can gain entry into their hosts through wounds. Both *Ustulina* and *Fomes noxius* sometimes infect tea bushes directly through wounds though that happens more frequently with *Ustulina* than *Fomes*. Then the fungus grows downwards to the roots. When these diseases are encountered at a distance from tree stumps it will usually be found that infection has occurred at a wound.

A food-base need not be the size of a tree stump. A small piece of wood is sufficient, particularly if it is a piece of root from a diseased bush. Although root diseases originate at stumps they are most frequently distributed as infected roots. For this reason diseased bushes should not be carried from one place to another except in closed sacks.

As *Ustulina* and Brown Root diseases originate at stumps the obvious method to prevent their occurrence is by having no stumps. Shade trees, however, have to be felled at times because they have grown too big or because their timber is required as firewood or for other reasons, and their stumps are not always easily disposed of. If the stumps are left *in situ* there is a possibility, but not a certainty, that root disease will originate there. Everything depends upon the arrival through the air of spores of particular fungi. Sometimes little or no disease results, but at others the damage from disease may be very extensive. No one can estimate the hazard with any accuracy. If, however, stumps are to be removed they should be dug out immediately after felling. If the stump is left for some months before removal, the fungus may arrive and grow into the roots during the interval. The removal of all roots of the felled tree is quite impracticable, and in any case an attempt to remove them would cause as much or more damage to the tea than any disease likely to arise from them would do.

As stumps are likely to be inevitable, the lodgment on them of spores from the air must be prevented. One way of preventing spores from falling on the wood surface is by cutting off the stump below ground level and covering it with a few inches of soil. When that is impracticable, as when giant Albizzias are felled, the bark should be removed and the stump thickly coated with tar on all sides.

Another and very ingenious method of dealing with this problem of tree stumps has been suggested and is well worth trial.

The principles involved are easy to follow. The trees to be felled are first ringbarked in order to kill them as described earlier (page 21). The roots die first after any food reserves they contain are exhausted. After death the roots are invariably invaded by numerous saprophytes from the soil. By the time the trees are felled many saprophytes are well established in the roots and any late comers, with or without parasitic powers, are at an immense disadvantage and have little prospect of obtaining a footing. Moreover as the roots are dead a fungus with parasitic powers has no opportunity of getting ahead of its competitors. In that struggle for existence the odds are in favour of the saprophytes. The idea is simply to crowd the roots with saprophytes before fungi like *Ustulina* and *F. noxius* can reach them.

At least in theory, if the trees are first killed by ring-barking there should be no necessity to remove the stumps. More experience of the method is necessary, however, before complete reliance can be placed on it. But if, in addition, the stumps are cut just below ground level and covered with earth or tarred as suggested earlier, the possibility of root disease originating at the stumps of felled trees will be greatly diminished.

When a bush dies of *Ustulina* or Brown Root disease it should be dug out completely together with as much as possible of the tree root which caused infection. No other treatment is necessary. Adjacent bushes, if their roots are in contact with other roots of the same infected stump may die later, but nothing can be done to prevent their deaths. Many of the adjacent bushes may not contact the stump or its roots, but which bushes they are cannot be determined by above-ground inspection. There is little risk of either of these diseases spreading from one bush to the next. All that is necessary therefore is the removal and destruction by fire of the diseased bush and such stump roots as can be located when the bush is uprooted.

Poria and *Rosellinia* differ from *Ustulina* and Brown Root diseases in that the last two normally originate at stumps and do not spread readily through the soil from one bush to another. *Poria* and *Rosellinia* diseases usually occur in patches and are not associated with stumps. In other respects *Poria* and *Rosellinia* have different habits and because of this the diseases caused by them will be discussed separately.

Since more attention has been paid to the removal of tree stumps, *Poria* disease has become the commonest root disease of tea in Ceylon, a position at one time held by *Ustulina*. Although

Poria hypolateritia can undoubtedly live saprophytically on wood as *Ustulina* can, the disease, somewhat surprisingly, rarely originates at a stump. The reason is that *Poria* rarely produces spores. Its fructifications are often encountered on diseased bushes, and though I have examined many, I have never found one bearing spores. The dissemination of this fungus as spores must be a rarity, which is fortunate ; otherwise the damage caused would be greatly increased.

Poria disease occurs principally in tea growing on land which was originally jungle and rarely in patna (grassland) clearings. In jungle clearings, the disease first occurs in the neighbourhood of a decaying jungle stump such as *Symplocos spicata,* which Petch states to have had the reputation of being its most frequent source. Those stumps have long disappeared, but the disease remains. The large bare patches where, over many years, diseased bushes have been removed are the places where the disease originally occurred. *Poria* disease is undoubtedly a legacy from the jungle. In the original jungle the fungus occurred, not as a virulent parasite but as a species struggling for survival on such material as it could feed on. When the jungle was cleared, the fungus survived as a saprophyte on decaying roots which served as food bases from which it could send out hyphae through the soil in search of more food. Those hyphae then encountered, not roots of jungle trees which they could not penetrate, but tea roots which they could. No matter in what direction the hyphae grew, some would be sure to encounter tea roots. The change was decidedly beneficial to the fungus. When penetration into the tea was achieved the fungus became independent of the original food base and took up a parasitic mode of life. Since then, the fungus has steadily progressed from bush to bush, using the infected roots of one bush as a food-base from which to reach the next.

Several years may elapse between the initial infection of a root by *Poria* and the death of the bush. During this time there is little or no evidence above ground that anything is amiss. Growth is slowed down almost imperceptibly, until suddenly the bush dies either wholly or in part. This gives the impression that the fungus kills quickly, which is far from the truth.

When dead bushes only have been removed from an infected area many of the apparently healthy bushes at the perimeter are infected, some very heavily and in due course will die and have to be uprooted. By that time the fungus will be established on adjacent bushes ; and so, treatment follows but never overtakes the fungus.

A method often recommended for stopping the progress of a fungus through soil is to enclose the area by trenches sufficiently deep to ensure that no root crosses them. In tea they were dug about two feet deep and the soil from them was thrown on to the enclosed area. The trenches were sited so that at least two rows of apparently healthy bushes around the bare patch were included within the isolated area. The method has proved a complete failure as a means of stopping the progress of *Poria* disease in tea and is now abandoned.

Measures now used for the control of *Poria* root disease are based on three main facts.

1. Many apparently healthy bushes on the perimeter of diseased areas are infected by the fungus.
2. Every infected root whether attached to a bush or not is a food-base from which the fungus can grow through the soil to other roots.
3. In the absence of food bases the fungus is relatively harmless. Hyphae in the soil, unattached to a food base cannot attack a living root.

The first stage in the treatment is to remove every infected root from the soil. This means the removal not only of every dead bush, but of every living bush no matter how healthy it may appear above ground, if even one of its roots bears the fungus. This can be assured only by uprooting bushes for examination until a complete ring of healthy bushes has been removed. The removal of a considerable number of really healthy bushes is sometimes objected to as wasteful, though no objection was raised when healthy bushes were included within an area isolated by trenches. Those bushes were all sacrificed to the disease, though several years elapsed before they died and could be removed. The immediate removal of healthy bushes involves a small loss of crop but that is more than compensated for by the elimination of the fungus from the area which can then be replanted.

No roots, living or dead, and no woody material which might become a food base should be left in the soil. Unless the bushes have been dead for some time and their roots have become very rotten, they can be extracted almost intact. Though some of the feeding roots break off during the process they can usually be recovered in bunches by a labourer running his fingers through the loosened soil. Small fragments of feeding roots if left in the soil do no harm and it is not worth while trying to recover them. The woody roots are the real source of danger.

Great care has to be taken that none of the woody material collected on the site is dispersed before it can be destroyed by fire. When diseased bushes or roots have to be removed from the site for destruction they should be carried in closed sacks. Yet it is inadvisable to have it collected directly into sacks. It is better to have a sheet of old jute hessian laid at a convenient place where the bushes, as they are removed and the roots as collected, can be thrown. The reason is that a labourer having picked up a short length of root, will sometimes throw it into the tea instead of placing it into a sack. The action is thoughtless rather than anything else. The pile on the sheet acts as a magnet and the smaller pieces of root are automatically thrown there instead of elsewhere. Other labourers, detailed for the work, fill sacks from the pile and carry them away for destruction.

After an infected area has been thoroughly cleaned in this way it may be replanted with tea as soon as convenient. Or green manures may be grown and later forked into the soil before replanting. *Tephrosia vogelii* was first recommended as an indicator crop because its roots are susceptible to *Poria* disease ; then, a dead *Tephrosia* indicated the position of an overlooked infected root. But experience has shown that when the work is carefully done this precaution is unnecessary, as many areas have been successfully replanted with tea immediately after treatment. Should a death occur amongst the young plants a search should be made for the source of infection.

In the past, labourers were allowed to take diseased bushes to the lines as firewood. On the way, diseased roots have been dropped and later have been swept off the path into the tea. The smaller *Poria* patches, frequently located near paths, have all started in some such way from diseased roots. There can be no objection to healthy bushes or even stem prunings from diseased bushes being taken away for firewood from areas being treated, but strict supervision must be exercised to prevent diseased roots being taken.

Rosellinia disease occurs more frequently on the drier side of the Island. The fungus produces a large number of spores (conidia) on almost every diseased bush, and some authorities recommend that the bushes should be flamed before removal to prevent the dissemination of these spores. That can be done by heaping straw or dry rubbish around the bush and burning it. Such treatment will of course destroy many spores but what of the myriads that were dispersed earlier ? A few more cannot make much difference.

Rosellinia like other root disease fungi of tea requires a food-base before it can start a parasitic existence. It is able to establish

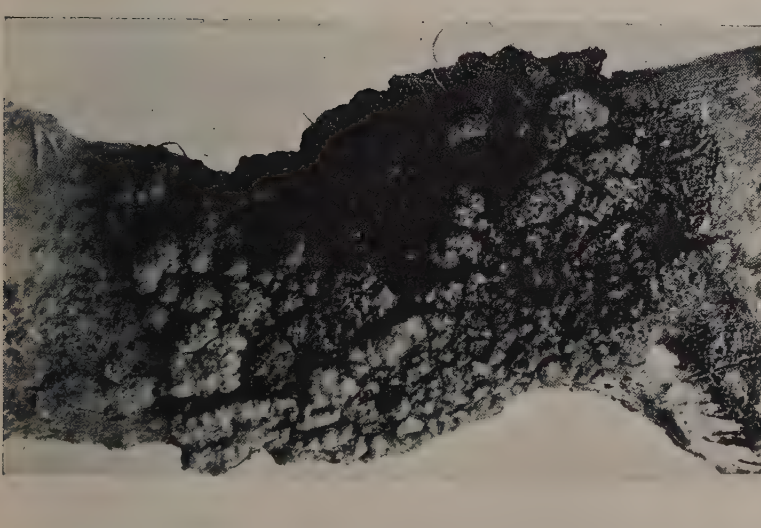
itself more easily on fallen leaves than on woody stumps, and for this reason, most probably, the disease rarely originates at stumps.

Rosellinia does its greatest damage when growing in a thick layer of dead leaves on the surface of the soil, during damp weather. Then, it grows at an extraordinarily rapid rate. When the fungus reaches a tea bush it encircles the stem and usually grows up it for a distance, but the main direction of growth is downwards towards the roots. The loose cobwebby mycelium is easily seen between the fallen leaves and on the tea stems. Growing in this way the fungus may attack and kill a large number of bushes almost simultaneously. A form of damage never seen on bushes attacked by other root-disease fungi often results from this type of attack. When a bush is invaded at ground level, where fallen leaves are in contact with the stem, the first tissues to be killed are those at the collar. The bush is then virtually 'ring-barked' though the bark remains in position. Sometimes, this is the only damage done if further progress of the fungus is stopped by dry weather, which kills the mycelium on the bush and in the fallen leaves. The ring-barking of course proves fatal, though the bush does not die until the food reserves in the root are exhausted. Meanwhile the bark above the dead ring at the collar becomes swollen as the food intended for the roots is arrested there. At this stage there is little to indicate what fungus killed the bush.

More frequently the fungus continues to grow downwards on to the roots and there behaves like a normal root disease, killing and rotting the roots. Although *Rosellinia* can pass from bush to bush much as *Poria* does, it has never done the same extensive damage nor proved so difficult to eradicate from an infected site. Possibly this is because it prefers a soil which contains a large proportion of dead leaves, and can spread through soil only in the upper few inches which is most liable to desiccation.

The appropriate treatment of *Rosellinia* disease depends upon the mode of its occurrence in the field. If as is often the case, the disease is obviously spreading through leaf litter this must be raked away from the main stems of the bushes and burnt. The bushes on which the fungus has established itself are best uprooted and destroyed immediately, before the bushes die. If, however, the disease occurs as a patch rather like *Poria,* it is advisable to treat it similarly, removing a ring of healthy bushes to ensure its eradication from the area. Particular attention must always be paid to leaf litter where this disease occurs.

PLATE 3.



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ROOT DISEASES.

1. *Ustulina zonata* — fructification at the collar.
2. Brown root disease — soil cemented to the root.

It is perhaps somewhat surprising that *Rosellinia arcuata* is not more frequently encountered, when the speed at which it grows through leaf litter and the large number of spores it produces are taken into consideration. Its potentialities to cause damage are great, and consequently the disease should not be regarded lightly. Prompt attention should be given to it wherever it is found.

The liming of soil from which diseased tea bushes have been removed was recommended at one time. Now it is known that lime serves no useful purpose in tea soils, being neither detrimental to the fungi which cause the disease nor advantageous to the bushes. In some places an application of lime may definitely be harmful to the tea. Lime should not be added to tea soils on any account except on professional advice.

A few details of two other tea root-diseases may be of interest though they are not common in Ceylon. The first is caused by the fungus *Fomes lignosus* Klotzsch which is well known to rubber planters. Though common in rubber, it is rarely encountered in tea except when tea and rubber are intergrown, or tea is planted on old rubber land. The disease it causes is generally known as *Fomes* in Ceylon. When an area of rubber is cleared preparatory to planting with tea, particular attention must be given to the stumps as on them may originate *Ustulina* and Brown Root diseases as well as *Fomes*.

Root splitting disease is caused by the fungus *Armillaria mellea* Vahl. The common name is derived from the longitudinal cracks which occur in the bark and wood of diseased bushes. The roots of young tea plants, about two years old may be split as with a knife. The fungus produces thick black cords of mycelium, termed rhizomorphs, which to some extent resemble shoe laces. These grow through the soil from the food-base and may be of considerable length. Their ability to set up new centres of parasitic activity seems to diminish as their length increases.

When the suitability of *Albizzia lopantha* as a shade tree for up-country tea estates was tested some years ago, many of the trees were killed by *Armillaria* though it rarely spread to the adjacent tea bushes.

The disease is not common in Ceylon, and when it occurs, it is usually associated with stumps. Treatment as recommended for *Ustulina* and Brown Root diseases is usually sufficient, but should it be found that the disease progresses through the soil from bush to bush, then a thorough cleansing of the soil as recommended for *Poria* disease should be carried out.

Other fungi have been recorded as causes of tea root diseases in Ceylon. Several are quite common on decaying stumps and diseased trees, but they rarely are parasitic on tea.

Rational treatment of any disease depends upon its cause, and accurate diagnosis is essential. When any doubt exists as to the cause of a disease, specimens, preferably entire bushes, should be sent to the Institute for examination. Though the treatments of tea root-diseases are somewhat alike, they differ in important respects. It may be essential to destroy apparently healthy bushes in some cases (e.g. *Poria*) but not in others (e.g. *Ustulina*).

LITERATURE.

Gadd, C. H. The parasitism of *Rosellinia arcuata*.—*Tea Quarterly*, **1**, 55-60 (1928).

— The treatment of *Poria* root disease.—*Tea Quarterly*, **2**, 16-21 (1929).

— The treatment of *Poria* root disease of tea.—*Tea Quarterly*, **10**, 36-45 (1937).

— The *Armillaria* root disease of tea.—*Tea Quarterly*, **3**, 109-113 (1930).

— Root diseases.—*Tea Quarterly*, **9**, 5-12. (1936).

— Root diseases and tree stumps.—*Tea Quarterly*, **9**, 101-107 (1936)

— Ring barking of trees and root diseases.—*Tea Quarterly*, **13** 117-123 (1940).

— Brown root disease.—*Bull.* **17**, 25-26 (1937).

Petch, T. *Fomes lignosus*.—*Tea Quarterly*, **1**, 64-66 (1928).

— Notes on Root diseases.—*Tea Quarterly*, **1**, 104-106 (1928).

CHAPTER 7.

STEM DISEASES.

Many fungi can feed on wood, but few can get that food so long as it is within an unwounded living tree, because the wood is covered and protected by a mass of living cells through which most fungi cannot penetrate. But when a tree is felled or a branch cut off, the wood is exposed and fungus spores may find lodgment on it. After the spores have germinated, the fungi even though they have no power of parasitism, will grow unhindered if they are able to use wood as food, because much of the exposed wood is dead. The part which is alive and functions in the transport of water, is near the exterior; the central part of the cylinder is dead. A growing branch increases in girth annually owing to the formation of new wood cells on the outer surface of the existing wood, and these carry on the work of water transport as the older cells cease to function.

The natural process of healing a wound is slow, very slow in tea. What is meant here by healing is the formation of a new protecting cover of living cells over the exposed wood — this new tissue is known as *callus*. It begins to form at the edge of the wound and gradually creeps in towards the centre, until the cover is complete. Such complete covers may be found over relatively small wounds in a tea bush but rarely over large wounds, measuring several inches in diameter. A wound made transversely across a stem, like the normal pruning cut, heals more slowly than a longitudinal one as made when a branch is cut off at its point of origin, flush with the parent branch. For this reason when removing a branch from any tree, it should be cut as close as possible, leaving no "peg."

Nature's method of healing a wound, because of the slow rate of callus formation, does not give the necessary protection against micro-organisms quickly enough. Some trees are able to set up, more quickly, another barrier through which many organisms cannot pass. It consists of a substance termed *wound gum,* and is situated just below the surface of the wound. Tea, however, does not form this barrier, possibly because it stores starch in its roots, not stems, — starch being the material from which wound gum is formed.

Very few trees carry as many wounds as a tea bush does. Every two or three years all its branches are cut back with a knife; and at times a saw is used to make still larger wounds. Every wound exposes the wood; so it should occasion no surprise that every tea bush has parts of its woody frame badly rotted. To this condition the name *wood rot* is applied. It refers to decay starting at pruning cuts, and brought about mainly by saprophytic fungi.

When a branch grows vertically, the wood rot runs vertically downwards, centrally in the branch, (Plate 5, Figs. 1 and 2) and it is by no means unusual to be able to force a walking stick some distance down the main central stems of many low-country bushes. The outer living layers of the wood continue to function even after the central part is badly rotted, and the bush does not appear to suffer any great ill effects from the decay. When a branch lies horizontally the rot occurs nearer the upper surface, and ultimately gives rise to a long cavity often as wide as the branch (Plate 5 Figs. 3 and 4). Except in wet weather the wood is dry but is so altered in texture that it can be removed by the finger nail. Even these ghastly looking branches carry at their extremities healthy vigorous shoots, well supplied with water.

The difference in position of the rot in horizontal and vertical branches may suggest different origins. In fact it is sometimes stated that the wood rot of horizontal branches originates as sun cracks. These are said to arise from the upper surface of horizontal branches becoming overheated by the sun after the bush is pruned; the bark is killed or cracked; and then rot-causing fungi are able to reach the wood through the injuries. Such injuries must occur before wood rot can start but I have never been able to find them in Ceylon bushes. That type of damage may occur in other tea growing countries, and the rot may then well originate in that way, but in Ceylon, the evidence indicates that the rot in horizontal branches, as well as in vertical branches, originates at pruning wounds.

As the rot starts at pruning wounds it will be obvious that some of the decay can be prevented by protecting the wounds from infection as soon as they are made. What is required is a cover through which fungi cannot pass, and which will be tolerably permanent and not liable to crack. Numerous different preparations, usually in the form of paints, have been recommended for the purpose. But whatever wound cover is used it has to be renewed

at frequent intervals until the wound is healed. None can give permanent immunity. Nor is any likely to prove 100 per cent efficient on tea for the following reason.

When a branch is pruned a bud bursts into growth some time later, and in due course becomes a branch replacing the one removed. The first bud to burst is usually that nearest the cut. The new branch may arise very near the cut, but more often, in tea, it is some little distance away. But whatever the distance, the stem between the cut and the uppermost new branch dies. There is then above the new branch, a cylindrical mass of dead tissue of which, if the cut had been painted, the upper surface only is protected. So micro-organisms can reach the wood through the dead bark. Despite the limitations of such protective treatment, large wounds should be covered with one or other of the preparations marketed for the purpose of preventing wood rot in tea.

Curative treatment has on occasions been carried out with some success. In principle it is rather like filling a decayed tooth. First all the decay has to be removed — not merely the soft rotten wood but the harder wood into which the organism may have already entered. Then, the cleaned cavity is painted or filled with material suitable for the purpose. Efficient work of this nature is obviously expensive, and the benefits gained from it are usually not commensurate with the cost.

Another method is to remove the worst branches at successive prunings. This, however, does not always work out well in practice. The removal of the larger branches entails saw-work which causes other large wounds, and unless special care is taken the treatment may cause more damage than the disease.

Wood rot may weaken the frame's structure to such an extent that in time an affected branch will break easily. The arrival of that day is delayed by the formation of new wood on the external surface of the woody cylinder, or, if the branch lies horizontally, on its lower surface. The amount of new wood formed depends to a large extent upon the foliage the branch carries ; the leaves will be situated on healthy branches arising from the decayed main branch. It is inadvisable, therefore, to remove these healthy branches merely because they arise from a decaying branch. The removal of the decaying branch itself entails also the destruction of any healthy branches it carries.

As with so many other diseases efficient protection is the only method of control. When the damage is done it usually cannot be mended. That is certainly true when the damage results in

badly rotted frames. When main branches are lost and the bush loses its crown of leaves it is better to replace the bush by another than to attempt rejuvenation.

Where scavenging termites occur they frequently invade the bushes to remove the decaying wood. They cannot digest sound wood, but when it is partially decayed it becomes an appreciated item in their diet. Because of the presence of termites in bushes the damage is sometimes attributed to them though they merely remove the decayed material and plaster the bush with ant earth while getting it.

Wood rot is generally caused by saprophytic fungi, but sometimes fungi with parasitic abilities reach the wounds and establish themselves there. *Ustulina zonata,* which normally causes a root disease, is one. Another is *Aglaospora aculeata* Petch which causes Thorny stem blight.

Thorny stem blight differs from wood rot only in that increased damage is done by a particular fungus, *A. aculeata,* which has some slight parasitic ability. Because of that power it gets ahead of its purely saprophytic competitors and kills the living cells. This causes the death of the invaded branch or of the entire bush if the decay is in the main stem. So far as is known this fungus cannot gain entry into the bush except at a wound, and it occurs mainly in up-country districts.

The disease cannot be distinguished from ordinary wood rot until the infected branch or bush dies. By the time that happens, the fungus is fruiting in the bark. The fructifications are easily recognised as black thorny projections from the bark (Plate 4, Fig. 1). Often they are easier to feel with the fingers than to see, until the bush is uprooted.

If the disease is recognised before the bush is dead any attempt to save it by pruning out the infected parts is inadvisable. The whole bush should be uprooted and burnt to avoid all risk of further spore production.

Before leaving the subject of wood rotting fungi on tea bushes it may be mentioned that bushes in the low country are more severely affected than those grown up-country. The reason for this may be two-fold. The organisms concerned vary to some extent with altitude, and the climatic conditions in the low-country are more favourable to the fungi.

Another group of stem diseases is known as "Canker." This term is applied to a particular type of injury, usually caused in the following way. An area of bark is killed by a parasitic fungus and then the activities of the fungus diminish or cease. The normal processes of stem thickening continue except beneath the dead zone and this results in the formation of a slightly sunken area. The dead bark may fall out and leave the wood exposed, though often the bark persists for some time. The healthy bark around the wound thickens as a callus is formed, and this tends to emphasise the depression. Often the callus is killed by further activities of the fungus, and this prevents the healing or the covering of the wound. Typically then, a canker is a dead area with exposed wood surrounded by a callus.

A canker results from two opposing forces. On one side is a parasite capable of entering and killing living cells, and on the other, a resistance which prevents the fungus from extending rapidly through the surrounding tissues. If there is no resistance, the fungus continues to grow, killing the tissues and extending the dead area.

A fungus which commonly causes canker on tea stems, mainly at low elevations, is *Macrophoma theicola* Petch. The fungus probably gains entrance into a stem while green and before a corky protecting layer is formed in it. By the time the stem is red a small elongated patch of bark is killed. At this stage the activity of the fungus appears to be arrested and a callus begins to grow from the edge of the wound but it never grows very far before it dies and a second callus starts to overgrow the first. Sometimes even a third callus is to be seen, but none ever reaches as far as the one it follows did. So the canker enlarges slowly, but no very great damage appears to be done. Occasionally, though very rarely, the bush appears to fail to put up its normal resistance and the fungus then invades and kills a very much greater area of bark without typical cankers being formed. The branch figured in Plate 4 (Fig. 3) shows two cankers. The smaller elongated depression in the branch on the left is a typical *Macrophoma* canker. The branch on the right carries a much larger canker with a thick callus at its upper edge.

This fungus like many others has two very different forms of fructifications. As fungi are classified by the characters of their fructifications, those with two types will have two names. The fructifications on the cankers caused by this parasite are of *Macrophoma* type and at that stage the fungus is known as *M. theicola*, but on the large areas of dead bark the fructifications are usually

of the *Physalospora* type and the fungus is then known as *Physalospora neglecta* Petch. Cankered branches should be removed when the bushes are pruned, partly on hygienic grounds to prevent further spore formation and dissemination, and partly because they weaken the branches to an extent that they lose resistance against other parasites.

One of the commonest and most destructive stem diseases of tropical trees and shrubs is Pink disease caused by the fungus *Corticium salmonicolor* B. & Br. Occasionally it occurs in tea seed bearers growing near jungle, but very rarely is it found in plucked bushes. The only time I have seen it in bearing tea, the bushes were pruned on a five-year cycle.

The disease gets its common name from the pink colour of the fungus growing on the surface of attacked stems, and this character makes the fungus easy to recognise. The pink encrustation often has numerous minute cracks in it usually at right angles to each other ; the sheet then appears as though covered witn a strange script.

The fungus penetrates the bark and interferes with the water supply to the leaves above the infected area, with the result that death of the branch follows. Any branches seen to carry the fungus should be cut off well below the pink encrustation and burnt.

Another disease which sometimes occurs in up-country fields during the first year from pruning is caused by the fungus *Leptothyrium theae.* This disease is recognised by the presence of solitary dead branches, with leaves attached, in otherwise healthy bushes. The branches usually come away quite easily with a sharp tug.

This fungus, like many other stem parasites, gains entry into the shoot while the stem is green and before it has grown to any appreciable length. The fungus then grows towards the base of the branch killing the cortex as it goes, and thence into the parent branch. Such infection appears to have no detrimental effect on the young branch at first although the stem may be ringed at the base. So long as water reaches the leaves in sufficient quantity the branch appears healthy. At the ringed zone no new wood is being made and other organisms are able to enter the wound with the result that ultimately there is a stoppage of water supplies and the death of the branch follows.

As the fungus usually enters the parent branch the mere removal of the lead young branch is not sufficient. The parent

PLATE 4.

1 2 3

STEM DISEASES

1. *Aglaospora aculeata* Thorny stem blight.
2. *Leptothyrium theae* canker encircling the main stem.
   The white line indicates the junction between living and dead tissue.
3. *Macrophoma* cankers. The canker in the branch on the left is the more typical.

branch also should be pruned at a point a little below where the affected branch is inserted. Special attention should be given to this pruning when the disease occurs in young supplies.

In a few cases the disease has been found to kill young bushes, by encircling and ring-barking the main stem. As the fungus can infect green stems only it will be evident that the main stem must have been infected while green or, more probably, infection occurred via a young branch arising from it. The fungus continues to grow slowly in the main stem and ultimately encircles it. Although virtually ring-barked, the bush even then shows no marked ill-effects until the food reserves of the root are exhausted. Without close and careful inspection infected bushes cannot be recognised till they die, apparently suddenly.

The bush shown in Plate 4, (Fig. 2) was completely encircled by canker. Its upper edge is marked by the swelling at the base of the branches and its lower by a white line painted on the specimen.

There are several other tea stem diseases which, with one exception, need not be mentioned here as they are by no means common. The one exception is perhaps the strangest disease of all. It occurs in mid and low-country bushes and is known as Red Rust or Algal disease. The latter is the better name, and the former should be dropped as that name is also used to denote a disease of tea caused by Red Spider. One name for two very distinct diseases leads to confusion.

The algae are a group of primitive plants provided with chlorophyll, and therefore do not have to live as saprophytes or parasites. They are perhaps best known as seaweeds, though many live in fresh water and a few are terrestial. One, by name, *Cephaleuros parasiticus* Karst, has acquired parasitic habits — a very unusual occurrence amongst the algae — and appears frequently as a parasite of tea.

Old tough leaves of many tropical trees and shrubs, including tea, often carry on their surfaces a number of small plants which live epiphytically. An epiphyte is one which grows on another plant without deriving any nourishment from it. The epiphytes on tea leaves appear as small flat discs of different colours and the red ones are usually *Cephaleuros*. *Cephaleuros parasiticus* usually gives up the epiphytic mode of existence and becomes a parasite on the leaf, as may be seen from the death of that part of leaf immediately below the alga. If this were the only damage, it would hardly be worth mentioning, but the alga also occurs on tea stems and is therefore a more serious parasite.

Cephaleuros fruits on both stems and leaves. The fructifications take the form of small red hairs each terminating in a small knob of spores. They resemble small red pins stuck upright into a flat pin cushion. This brief description might apply equally well to a few other organisms (fungi). Mistaken identity is unlikely, however, if the red patch occurs on dead areas of leaves or on parasitised tea stems.

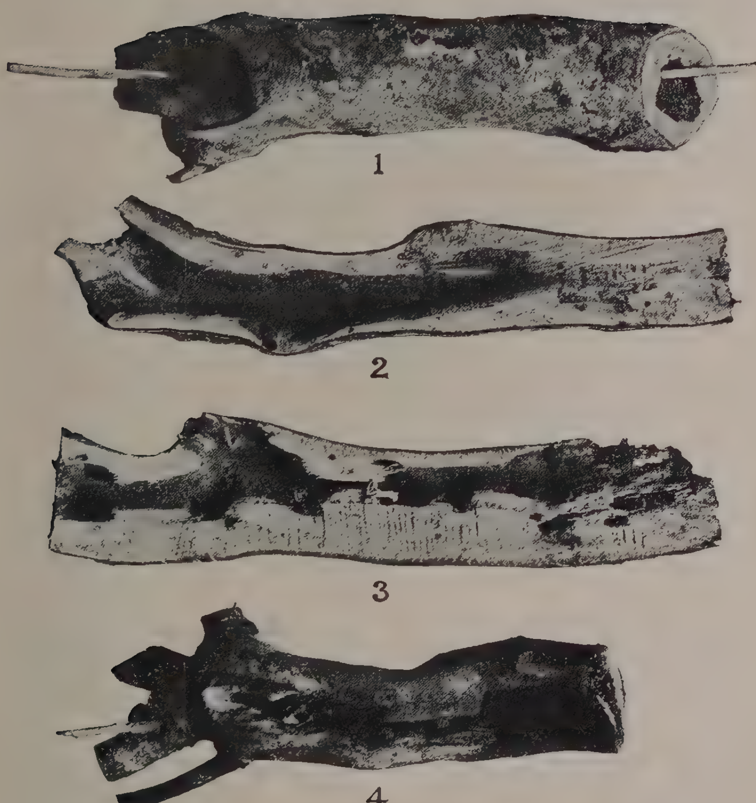
The parasitised stems are very easy to locate because their leaves are variegated, green and white or green and pale yellow, and they are usually situated around the perimeter of the bush. The stems usually bear large patches of the alga easily recognisable when fruiting. The reason for the leaves becoming variegated when the stems carry this alga is not known. There is another and somewhat similar form of leaf variegation, not associated with *Cephaleuros,* which is in the nature of a bud sport, but as it is unlikely to occur on many bushes in a field it is rarely mistaken for the variegation characteristic of algal disease.

Cephaleuros appears to be unable to establish itself on vigorously growing branches. For this reason the disease is usually said to be one of weak bushes. That is true up to a point as the disease appears worst in bushes growing in poor soils. Poor drainage, shallow soil, lack of manure and any other condition leading to poor growth will favour the disease.

But diseased branches are to be seen in vigorous bushes and in fields where the bushes are otherwise in good condition. The whole evidence there is against the soil conditions being in any way unsatisfactory or the bushes being undermanured. A careful examination of the diseased branches will usually disclose the presence not only of *Cephaleuros* but also, below the region occupied by the algal parasite, a canker, such as is caused by *Macrophoma.* The canker provides the clue to the problem. The algal parasite establishes itself on a weak branch, not necessarily a part of a generally weak bush.

Where the disease results from adverse soil conditions attention must be given primarily to their amelioration. More often, in Ceylon, the trouble lies in the bush itself and then particular attention must be paid to pruning out the cankers. As what has earlier been described as Wood rot was at one time known as Branch canker, it may be advisable to state that the cankers, now referred to, are not the large cavities of decaying wood but the smaller cankers caused by parasites on the smaller stems. The disease is most prevalent at altitudes where the bushes cannot

PLATE 5.



Block by Survey Dept. Ceylon.

WOOD ROT.

1. Vertical branch, hollow.
2. Section through a vertical branch to show position of rot and its extent.
3. Section through horizontal branch showing rot near the upper surface
4. Horizontal branch with rotted cavity in the upper side.

safely be clean pruned. Where cut-across methods of pruning are used, there is little opportunity of cleaning the bush of its diseased branches. This makes necessary a periodical pruning on some such system as the "rim lung prune" which allows a better cleaning of the bushes. Close attention to the removal of cankered branches will do much to eliminate this algal disease.

LITERATURE.

Gadd, C. H. Pruning in relation to wood rot of tea.—*Tea Quarterly,* **2,** 10-16 (1929).

— The pruning of tea in relation to disease.—*Tea Quarterly,* **4,** 45-53 (1931).

— Wood rot.—*Bull.* **3,** 12 (1929).

— *Leptothyrium theae.—Bull.* **13,** 29-31 (1936).

Petch, T. Wood gum.—*Tea Quarterly,* **1,** 27-30 (1928).

— Callus.—*Tea Quarterly,* **1,** 67-71 (1928).

Tubbs, F. R. Wound healing processes.—*Tea Quarterly,* **5,** 22-24 (1932).

— Dieback.—*Tea Quarterly,* **5,** 108-111 (1932).

CHAPTER 8.

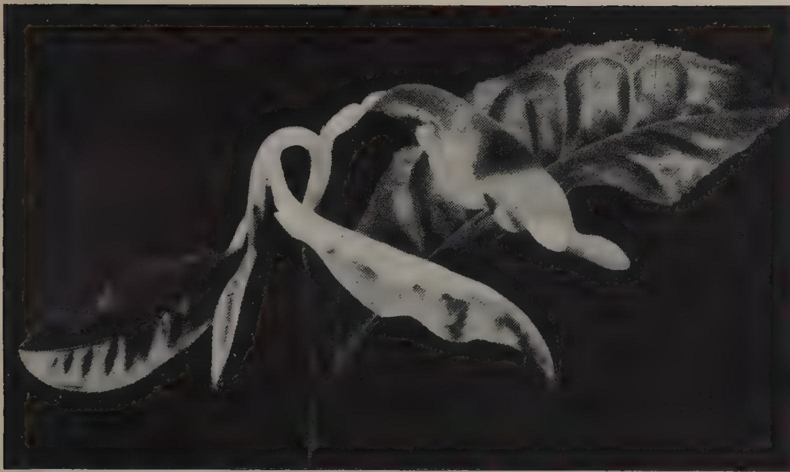
LEAF DISEASES.

The disastrous effect of the coffee leaf disease has left no doubt in the Ceylon planter's mind regarding the importance of fungus diseases, particularly those affecting leaves. The tea bush is cultivated for its leaf, and for that reason, if no other, the tea planter is particularly alert to notice the occurrence of leaf diseases of tea. In consequence, numerous leaf diseases of tea are recorded, but none had proved of serious importance till the arrival of Blister Blight in 1946.

The first to be noticed were Grey Blight and Brown Blight. Both can be recognised by the brown dead areas, of varying size. in the affected leaves. Sometimes the greater part of the leaf is killed. Typically, Grey Blight differs from Brown Blight in that the dead tissues of leaves affected by the former gradually turn grey, whereas in the latter they remain brown, and become so brittle that pieces fall out leaving the veins with fragments of dead leaf tissue attached (Plate 7, Fig. 3). These differences are not very reliable, and the identification of the fungi on the diseased leaves is usually necessary for definite determination. *Pestalozzia theae* Sawada is the fungus associated with Grey Blight, and *Colletotrichum camelliae* Massee with Brown Blight. Very often both fungi are found in the same dead zone, and as the dead tissues are usually brown the disease is called Brown Blight whether the fungus *Pestalozzia* is present or not.

Spores of both fungi are very abundant in the air of any tea field, and they are deposited as dust on the leaves. Nevertheless very few leaves become diseased. The reason is that both fungi are very weak parasites of tea, better adapted to saprophytic than parasitic existence. In all probability neither fungus is capable of obtaining its nourishment from living cells of a tea leaf unless the cells are so damaged as to be moribund.

At times Brown Blight is reported to be damaging young leaf seriously. Such damage usually occurs a few months after pruning and as soon as the bushes are tipped. What then is the connection between tipping, the shortening of young branches, and the occurrence of Brown Blight ?



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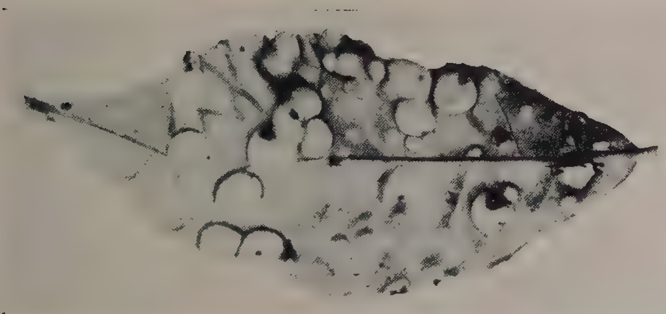

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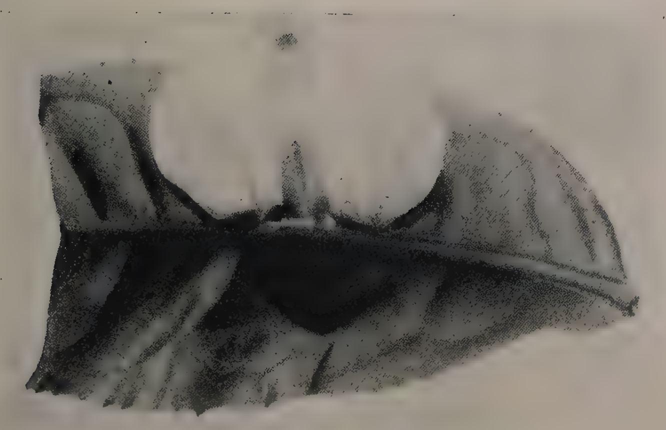

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BLISTER BLIGHT (EXOBASIDIUM VEXANS)

1. Stem and leaf infections on tea shoot.
2. & 3. Blistered tea leaves.

It is not generally recognised how very susceptible to injury from direct sunlight are tea leaves, particularly young ones when they have become accustomed to shade. When the shade is removed gradually the leaves undergo a change which protects them against sun injury, but if it is removed suddenly the damage to young nursery plants may be very extensive. The same is equally true of young leaf growing on mature bushes in the field though the nature of the shade is different. When tippings are removed the young leaves which have previously been shaded by the growth above them are suddenly exposed to direct sunlight and injury results. The damage is usually not extensive as relatively few leaves are so heavily shaded as to become very susceptible to direct sunlight.

The nature of the damage is best described as a scorch, and is termed *sun-scorch*. The surface of the leaf, usually only a part of it, becomes reddened, and though the affected cells may not be killed outright they become moribund and lose their power to resist certain parasites. At this stage, the fungus *Colletotrichum camelliae* comes into the picture. Its spores are so abundant that some are certain to be on the injured leaves. Entry is gained immediately and the injured cells are quickly killed and turn brown. The fungus, however, is incapable of advancing beyond the sun-damaged area into the uninjured tissues (Plate 15, Fig. 1).

This ability of the Brown Blight fungus to enter moribund cells will be referred to again later. The initial cause of Brown Blight is not the fungus, but some other agent which first damages the cells. When the disease follows tipping, the initial cause is usually sun-scorch and its apparent spread ceases when tipping is completed.

Exobasidium vexans Massee which causes Blister Blight is a fungus occupying a place at the other end of the scale of parasites. It is an obligate parasite incapable of getting its nourishment from dead matter, and so far as is known, able to get it only from living tea bushes. Its arrival in Ceylon created considerable alarm at first, as no one could estimate with certainty the extent of damage it might do under Ceylon conditions. As its habits became known and methods of control were devised, the fears it engendered dispersed. But the disease will remain one of prime importance and be a constant source of worry and annoyance to planters.

The fungus reached Ceylon in one of two forms, either as ungerminated spores carried in the air or attached to merchandise, or as a growing organism in living tea plants. The import of seed and other planting material into Ceylon has been prohibited for

many years and though a living plant may have been smuggled into the country, it seems unlikely that the disease reached Ceylon in planting material. More probably the fungus arrived as spores, in the wind, from South India. How the fungus reached South India prior to getting to Ceylon is a matter on which no opinion can be offered here. But it will be evident that although spore dispersal through the air cannot be restricted, the movement of plants from one country to another must be a matter for careful control. All governments should receive the strong support of every agricultural community for such restrictions on the movement of seeds and living plants as are deemed necessary.

Exobasidium vexans spores are very small and are carried long distances by wind. Ultimately they settle as dust, and when wetted, begin to grow if still alive. They are not long lived and unless they obtain water within two or three weeks they die. Exposure to direct sunlight or to moderately high temperatures for even a few hours kills them quickly. Blister Blight is unlikely to become very prevalent in the low-country of Ceylon because of the high temperature, though occasionally it will be found there.

The spores are sticky and adhere firmly to any surface on which they fall. Growth starts within a few hours of the spores getting the necessary water. First, small tubes (hyphae) emerge from each end of the spore and gradually elongate. While still rather short growth ceases and a special organ, termed an *appressorium,* is formed at the end of each. The appressorium is circular, flattened and dark coloured ; it adheres very firmly to the surface on which it is formed. If that surface should be a suitable leaf, a very fine thread emerges from the underside of the appressorium and pushes its way into the leaf. When the thread has passed through the cuticle (skin) and wall of an outer cell, it swells and becomes a normal hypha within the cell. This process of entry is entirely mechanical and considerable force has to be exerted for success. Unless the appressorium adhered very firmly, the pressure exerted, instead of forcing the thread into the leaf, would cause the appressorium to lift and entry could not be achieved.

The fungus cannot force its way into every leaf, even of tea. Entry is gained most easily into very young leaves as they unfold from the bud, and it becomes increasingly difficult as a leaf ages. For this reason, fully developed leaves are never infected. The increased resistance against penetration may be due to a thickening or hardening of the cuticle, but the exact nature of it is not understood.

What has so far been described can be followed only with the aid of a microscope. To the naked eye nothing is to be seen, and the leaf shows no sign that it has been parasitised till about a week later. Then the place of entry becomes visible as a light coloured, translucent spot which gradually enlarges. By that time the fungus is well established in the leaf tissue. Its mycelium lies mainly between the cells, though special short branches pass into the cells to obtain nourishment. The invaded cells do not die; instead, they begin to enlarge slightly. The expansion of the invaded area causes it to bulge and so to form the characteristic blister. The bulge is usually towards the lower surface of the leaf though sometimes it is in the opposite direction. By the time the blister is formed the fungus is about ready to fruit, and a dense mass of mycelium has grown beneath the leaf's lower surface, with the hyphae arranged almost parallel like the pile of a carpet. The outer covering of the leaf breaks and flakes off, and the fungus becomes visible as a white velvety mass. At this stage, about 18 days after infection, spores are produced in prodigious numbers over the whole of the white surface (Plate 6, Figs. 1—3). The nutriment to make and supply these spores with food is extracted from the invaded cells, which when completely exhausted die. The fungus dies too and the blister becomes black.

The size of the blisters depends to some extent upon the number formed on a leaf, being smallest when most numerous. The largest blister rarely exceeds two inches in diameter. There appears to be a limit to the area which can be invaded by the fungus developing from one spore, and that suggests the setting up, within the leaf, of a barrier beyond which the fungus cannot pass. Otherwise it is difficult to understand why the fungus does not continue to grow and invade the whole leaf. The nature of the barrier is not known.

The fungus invades very young green stems as well as leaves, and the damage resulting from such infections is rather more severe than those in leaves, as the stems are girdled and killed (Plate 6, Fig. 1).

The most critical period in the life of the fungus is from the time the spore is liberated until it has germinated and entered a leaf. Whether it will survive or not depends largely upon the weather. Water is essential from the time the spore begins to germinate until the fungus is established within the leaf. In the laboratory that period may be as short as eight hours, but in the field where conditions are not so favourable it is probably considerably longer. Evening dew provides sufficient water to start germination, but if infection is to be complete the dew must persist sufficiently long for the young fungus to enter the leaf. As numerous

infections do not occur every night that dew forms, it seems probable that the time a leaf is normally wet with dew is not quite long enough to allow infection. When dew persists longer because of dense shade or other factor which delays drying, many infections occur. Damp, sunless weather provides ideal conditions, and most infections occur then. The results of the infections are not very prominent until about three weeks later, when the blisters are fully developed.

As sunshine is detrimental to the fungus it may appear reasonable to suppose that the removal of shade trees, to allow as much sunlight as possible to reach the bushes and accelerate the evaporation of dew, will be an important aid in the control of the disease. The weather most favourable to the fungus, however, is characterised by the absence of sun, and at such times it is immaterial whether shade trees are present or not. Their presence cannot increase or diminish the incidence of the disease. Removal of shade may reduce the incidence of the disease at times of minor attacks, but is almost valueless when weather conditions are suitable for a major attack. Where shade is dense it should be controlled, particularly in areas where dew persists overlong during fine weather, but its complete removal, in view of the good reasons for the original planting, should not be contemplated.

The most fortunate characteristic of Blister Blight is that it causes little or no damage to fully expanded mature leaves. If old leaves were damaged as young leaf is, the survival of tea as an economic crop in many parts of Ceylon would be doubtful. What will save the tea bush is its permanent foliage, the leaf which does not go to market. That fact must not be forgotten when control measures are considered.

The most dangerous time for a tea bush is during recovery from pruning, when all its leaves are young and few or none are mature. At this stage the loss of young shoots and leaves is a vital matter. They can be replaced only at the further expense of food reserves, which repeated withdrawals for leaf replacements must ultimately exhaust. The planter's viewpoint may be somewhat different. He will note the long delay in getting his bushes back into bearing and the frequency of deaths amongst them.

It is therefore a matter of prime importance that bushes should pass through this critical period at a time when weather conditions are least favourable to the parasite. Pruning must be timed to allow of recovery during the most favourable months for the bushes. The optimum time will vary to some extent from place to place,

and it can be determined only from exact knowledge of the locality. It depends on two main items (1) the months when the disease is normally at a minimum and (2) the length of time normally taken by the bushes to recover from the particular type of pruning adopted. The objective must be to have a good cover of mature leaves on the bushes whenever the disease is likely to be prevalent.

Pruning, where it has to be completed in a relatively short period, has created a number of managerial problems in the solution of which the following suggestions may assist. When the area to be pruned cannot be completed during the optimum months, it is better to start earlier than to continue later. Also, as the length of time required by bushes to recover from pruning depends upon the kind of pruning, a lighter type may be advisable in some fields. In general, however, there appears little need for many estates to alter radically their type of pruning because of this disease. Fields liable to be enveloped in mist create special problems, but the same principles apply. How best to apply them can be determined only from a knowledge of the individual fields. The experience gradually accumulating on each estate will, in due course, form the soundest basis on which to found pruning programmes.

There appears to be a difference of opinion regarding the best type of plucking at times when the disease is severe. When the disease is most severe, bushes make little growth, not because the disease is stopping their growth, but because the sunless cold weather does not suit the bush. At such times, when the amount of crop to be harvested is very small, it would be preferable not to pluck at all. The removal of shoots stimulates the formation of others which is not, at such times, advantageous for the bush. Plucking problems exist, however, whenever the disease is prevalent.

The generally approved standard of plucking for normal times is two leaves and a bud, leaving one full leaf above the fish leaf on the bush. Plucking is restricted to shoots above the plucking level ; any young growth within the bush or at the sides below that level is left alone. When the disease is prevalent, the third leaf is usually so damaged that it is of little or no use to the bush, and certainly of no use in the factory. There is, therefore, no apparent reason why the shoot should be allowed to reach that stage of development or why any leaf should be left for the bush at such times. This suggests 'close' plucking. What is required in the factory is young leaf undamaged by the disease. As three weeks elapse between infection and the full development of the blisters, it follows that no leaf for manufacture should be that age, preferably not more than 14 days old, counting from its unfolding from

the bud. That does not mean that plucking rounds should be of that interval. Rounds should be short, and no young leaf liable to develop blisters should be left above the plucking level.

Such plucking is severe, and should be used only during times of severe attacks. If the bushes have a good cover of leaves when the attack and severe plucking start, they will come to no harm. Severe plucking is only a part of the treatment ; the other is equally important. During the attack no new leaf has been added to the bush's permanent foliage. This can be remedied only by lighter plucking for a few rounds later, to make good that deficiency.

The most efficient method of protecting plants against a specific fungus is to coat them with a thin layer of a substance poisonous to the fungus. Copper fungicides are efficient against *Exobasidium* and they may be safely used on young plants in a nursery or on bushes which are not to be plucked. The spraying of fields should not be necessary except under exceptional circumstances and it is hardly likely to prove economical as a general practice. When tea plants are sprayed it should be remembered that the young leaf needs protection, not the old. As any new growth formed after the spraying is completed is unprotected, it will be evident that the operation has to be repeated at frequent intervals, not greater than a week. Spraying is a form of protection and must be started as soon as the weather becomes favourable to the disease. If it is delayed until blisters appear it will obviously be three weeks too late.

The most efficient protection against the fungus is a strong natural resistance. In any tea field a few bushes, the most susceptible, will carry blistered leaves whenever climatic conditions are the least bit favourable, and when the majority of bushes have none. Also there are others, of a strongly resistant type, which have few or no blisters when the surrounding bushes are badly attacked. The bushes behave consistently, and there is every gradation between very susceptible and resistant. The very resistant ones are important. Such bushes should be sought for and, unless obviously unsatisfactory for other reasons, should be propagated vegetatively on a small scale. Amongst them will be found some having other desirable characters, such as high yield and good quality and these should be propagated more extensively to provide planting material for supplying and planting new areas. The selection and propagation of the best will take time. Work along these lines has started and there are good prospects of success.

Earlier it was stated that the Brown Blight fungus, *Colletotrichum camelliae,* is able to invade only those cells whose resistance has been lowered by injury. Cells invaded by *Exobasidium vexans* lose their resistance against *Colletotrichum* with the result that the latter fungus often follows the former into leaves. When *Colletotrichum* enters the leaf it kills the damaged cells quickly, usually well in advance of its own position. This stops any further growth of *Exobasidium* and the invaded areas blacken prematurely, often before *Exobasidium* has started to fruit. *Colletotrichum* then produces its own spores on the dead area.

So far as can be ascertained *Colletotrichum* does not penetrate beyond the cells invaded by *Exobasidium;* the damage is not extended. This secondary invasion very markedly reduces spore production and consequently the incidence of Blister Blight, though not sufficiently to be regarded as an effective control.

Another fungus, also found in association with prematurely blackened tissues during a Blister Blight epidemic, though more frequently on young stems than on leaves, is best known as the cause of the Cercosporella leaf disease of tea. Cercosporella disease was first observed by Petch in 1909 and he later described the fungus which caused it, as *Cercosporella theae.* Recently, the fungus has been transferred to another genus *Candelospora* and its correct name now is *Candelospora theae* (Petch) Wakefield. It also has yet another new name because a second form of fruiting body has now been described and named *Calonectria theae* Loos. As there is no common name in use other than the old generic name of the fungus the disease will be referred to as Cercosporella disease and the fungus which causes it as *Calonectria.*

Cercosporella disease occurs in two forms. The first, which is commoner and less destructive, can be recognised by the young leaf being spotted and corroded. The spots are small and may be very numerous. The apparent corrosion is due to the leaf being attacked and small areas killed before the leaf has expanded. As the undamaged parts expand the dead areas fall out and leave irregular holes somewhat suggestive of insect damage (Pate 7, Fig. 1). The second form is more severe and is characterised by defoliation.

The incidence of the disease is dependent on two factors (1) persistent mist and (2) the presence of *Acacia decurrens* or certain other trees. The form of the disease depends mainly upon the duration of the mist.

Where *A. decurrens* is intergrown with tea and the area becomes enveloped in mist with relatively short clear intervals, the young leaf becomes severely spotted. During wet weather, a few spots may be seen on young leaves in fields where no Acacias are growing and where mist is not prevalent, but the damage is then so small as to be of little or no importance. But the disease cannot be ignored when mist and Acacias occur together. The young leaves may then be so badly spotted as to be useless for manufacture (Plate 7, Fig. 2). Each spot probably results from a spore infection. The leaf retains its normal green colour and does not become pale as the photograph suggests.

Where the mist persists for weeks on end — a somewhat unusual occurrence — the effect is different. The Acacias shed their leaflets which fall on and adhere to the tea leaves, both young and old. Each infected leaflet acts as a food-base from which hyphae grow as a fine web over the surface of the tea leaves. The disease then appears, not as spots, but as large diffuse patches on old as well as young leaves, and often the whole leaf becomes diseased. At this stage the bush sheds the diseased leaves, and may be completely defoliated.

The fungus *Calonectria* is more prevalent in tea fields than was previously recognised as it lives saprophytically on dead leaves. The disease it causes in tea has, however, become one of minor importance since Acacia trees have been removed from fields where previously it occurred in severe form.

Many other leaf diseases have been found in Ceylon tea bushes at different times but they have not proved to be of any real importance. Some cause diffuse patches like Brown Blight, and others spots like Cercosporella disease, and skilled examination is necessary for diagnosis. They usually result from some very local condition of a temporary nature.

One which does not fit very well into such a generalisation, judging from the frequency it is sent to the laboratories for identification, is known as Scab. It occurs on old leaf only. A few affected leaves can be found in most tea fields. A part of the surface of affected leaves is somewhat irregularly blistered and cracked, somewhat elevated and often grey intermingled with black. Its name, Scab, affords as good a short description as any. The fungus associated with this disease is *Elsinoe theae* Bitancourt & Jenkins but little is known about it (Plate 7, Fig. 4). The disease is of no economic importance.

PLATE 7.

LEAF DISEASES

1. Cercosporella leaf disease — old attack. 2. Cercosporella leaf disease — current attack. 3. Brown blight. 4. Scab.

LITERATURE.

Tubbs, F. R. Blister Blight.—*Tea Quarterly*, **18**, 90-91 (1946).

— Blister Blight (and discussion).—*Tea Quarterly*, **19**, 9-16 (1947).

— The Control of Blister Blight of Tea.—*Tea Quarterly*, **19**, 34-41 (1947).

— A leaf disease of tea new to Ceylon.—*Tea Quarterly*, **19**, 43-45 (1947).

— Notes on Blister Blight.—*Tea Quarterly*, **19**, 50-56 (1947).

Allday, C. Blister Blight — The influence of early tipping on yield.—*Tea Quarterly*, **19**, 45-48 (1947).

Vander Kiste, W. R. Blister Blight.—some financial aspects of its control. —*Tea Quarterly*, **19**, 48-49 (1947).

Gadd, C. H. The collection of blistered leaves.—*Tea Quarterly*, **19**, 17-19 (1947).

Gadd, C. H. and Loos, C. A. The fungus *Exobasidium vexans*.—*Tea Quarterly*, **20**, 54-61 (1949).

CHAPTER 9.

NURSERY PLANTS.

The diseases of seedling and young tea plants are not markedly different from those of mature bushes. Young plants require more protection, not because of a greater susceptibility, but because damage is more likely to prove fatal owing to their tender age. Nursery conditions differ from those of the field, and as may be expected, some diseases are more evident under one set of conditions than the other. The diseases included in this chapter are those encountered more frequently amongst nursery plants than more mature bushes.

"Bitten off" disease is probably the commonest disease in nurseries. Brief reference to it was made in Chapter IV where one of its causes was stated to be an excess of water. More frequently the same, or very similar, symptoms are induced by an entirely different agency.

The name "Bitten off" refers to the appearance of the plants when hand pulled. The finer roots and, often, the taproot have disappeared as though bitten off by insects. When the plants are carefully lifted from the soil, the roots are found to be decayed. (Plate 8, Fig. 1). The first indication that anything is wrong is the general unthrifty appearance of the plants; the leaves are crowded together near the apex of the shoot and the older leaves fall prematurely. Eventually growth ceases; the leaves fall and the plants die. By that time not only have the finer roots disappeared but the greater part of the taproot also.

For a long time the cause of this disease remained obscure though it was known to occur most frequently in nurseries made on sites of old buildings and line gardens. Sometimes all the tea plants within the nursery are affected; at others the disease is more pronounced in certain beds. Diseased and healthy plants are never intermixed. Attempts to cause the disease in healthy plants failed, when fungi associated with the decay of diseased roots were placed in the soil around the healthy roots, but they succeeded when the soil was kept too wet, even though no fungus was used. The experiments offered one explanation of the cause of the disease, but it could not be accepted as entirely satisfactory because the

disease occurs in nurseries where soil moisture conditions are eminently suitable. The problem was obviously not solved completely at that stage of the investigation. The answer was found when more became known about the healthy tea plant.

Tea requires an acid soil and will not tolerate an alkaline one. Rainfall, temperature and other general conditions may be eminently suitable for tea culture but unless the soil is markedly acid tea plants will not thrive. The roots die and decay. In this respect tea's requirements are very different from the majority of crop plants and they are best fulfilled by the leached soils of the tropics. The most favourable range in the pH scale of acidities for the majority of crop plants lies between 6.2 and 7.2, but tea prefers soil with a pH value of 5.5 and will not grow normally when the value exceeds 6.0. The symptoms become more pronounced as the pH value increases. But what is this pH scale ?

Though the symbol "pH" is readily interpreted by physicists no explanation of it will be offered here. It may be accepted as a scale just as the yard is a scale for measuring length. On that scale pure water is given a value of 7.0 which may therefore be interpreted as neutrality. The lower a pH is, the greater the degree of acidity it represents ; and the higher the value above 7.0 the greater is the alkalinity. Moreover, the scale is logarithmic ; that is to say, a whole number on the scale, say 6, represents an acidity ten times greater than that represented by the next whole number 7, and 100 times greater than that of the following number 8. Arable soils normally range between 4 and 9 on the pH scale ; the former value represents an acidity 100,000 times greater than the latter.

What is measured by the pH scale is not the quantity of acid but its strength or intensity. The difference may be illustrated by comparison with the thermometer scale. Two bodies may be at the same temperature, but one, because of its greater size or of a difference in composition may contain more heat than the other. A quantity of heat cannot be represented on a thermometer scale, nor can the amount of acid be measured by the pH scale. Much as temperature, not total heat, affects the growth of plants, so does pH, and not acid content, determine whether a soil is suitable for a particular species of plant.

The pH of a soil can be altered by the addition of acids or alkalies. Some fertilisers tend to alter the pH, for instance sulphate of ammonia tends to make a soil more acid. That is one reason why sulphate of ammonia is usually preferred as a source of nitrogen

for tea. Lime is used generally in agriculture to prevent the soil becoming acid. At one time lime was recommended for use in the treatment of tea root diseases, but it is now known that its detrimental effect in reducing the soil acidity far-outweighs any benefit derived from its use.

Old building sites usually contain mortar and lime rubble, and labourers' gardens usually are manured liberally with wood ashes. Both lime and wood ash tend to increase the pH value of a soil and make it less suitable for tea. When the soil has too high a pH value, tea seedlings growing on it soon begin to exhibit symptoms of "Bitten off" disease and these become more severe as the pH increases.

Mention must also be made here of the detrimental effect of compost in this respect. It should not be applied in undue amounts in supply holes, nurseries or baskets for tea plants because of its alkalinity.

Although "bitten off" is primarily a disease of seedlings, any adverse change in the pH of soil in which mature bushes are established will affect them detrimentally. The poor condition of bushes in the immediate vicinity of some factories is due to a large quantity of ash from the factory driers having been spread on the soil. Of course, tea cannot be established on lime soils, and bushes growing in the vicinity of limestone outcrops are often in poor condition for the same reason.

Unsuitability of soil cannot always be corrected, nor can anything really satisfactory be done for the plants after the disease occurs. When nursery sites are being selected, the soil's pH should be tested before the seeds are planted as much disappointment and loss can be avoided thereby.

"Damping off" is a disease of seedlings in general, well known to gardeners everywhere. It is characterised by the shrivelling of seedling stems at ground level and the consequent toppling over of the young plants. Several fungi are known to cause this disease and all normally live in the soil. But when the seedlings are overcrowded and conditions are very humid, the fungi spread over the soil surface and attack the seedlings at ground level as they are encountered. Its name suggests the conditions which lead to the disease. It implies damp conditions, but not necessarily overwatering as the disease does not result from excess water at the roots but high humidity and a lack of air circulation around the plants.

The commonest fungus known to cause "damping off" in Ceylon is *Rhizoctonia solani* Kuhn. and it is sometimes, though not very

often, encountered on tea seedlings. It does not, however, produce typical "damping off" symptoms on tea seedlings as the stems of even very young plants are too stout to fall over when killed at ground level. When the seedling stem has formed a thin layer of cork around the base of the stem the fungus is unable to enter the plant at ground level and it must climb the stem to reach the succulent green shoot and leaves. This it can do only when conditions are very favourable and then the young shoot and leaves are killed.

As *Rhizoctonia* is by no means an uncommon fungus in Ceylon soils it is perhaps surprising that the disease is not more frequently encountered in tea nurseries. The reason is probably that the fungus cannot normally overcome the natural resistance of the tea plant to it, and very humid conditions either decrease the plant's resistance or increase the fungus's virility. Whatever may be the reason, it is clear that this disease affords another example of the importance of environment in the causation of disease by fungi. When this disease occurs in tea nurseries it is usually the result of poor cultural conditions.

Another fungus *Sclerotium rolfsii* is somewhat similar to *Rhizoctonia solani* and has much the same effect on tea seedlings. Its white fleecy mycelium runs through the surface layers of the soil and sometimes forms a white crust. The affected stems are covered for a short distance at first with white strands of mycelium, and later with small spherical bodies, at first white, but pale yellow or brown later, and about the size and shape of mustard seed. These spherical bodies are compact masses of mycelium, termed *sclerotia,* which will withstand desiccation. They enable the fungus to survive in the soil from one wet season to another.

Rhizoctonia solani also occurs occasionally in mature bushes growing in the warm humid atmosphere of the Low-country. The fungus then behaves much the same as on tea seedlings. It grows on and up the main branches as very fine hyphae, practically invisible to the naked eye, without doing any apparent damage until the leaves are reached. It then forms a thin cobwebby weft on their lower surfaces killing large areas of leaf surface and sometimes entire leaves. The diseased areas turn brown or greyish brown as though invaded by *Colletotrichum,* the Brown Blight fungus. The fungus often fruits on apparently undamaged leaves. The fructification occurs as a white or greyish coating on their under-surfaces. Under a lens it has the appearance of a loose, narrow-meshed net-work of hyphae. The fungus at this stage is known as *Corticium vagum* B. & C.

When the dead leaves fall they often remain suspended by thin cobwebby threads and may become loosely webbed together. The attachment to the bush of fallen leaves by fine threads is characteristic of this disease and others caused by this type of fungus. Black rot of tea caused by *Corticium invisum* has somewhat similar symptoms, but though well known in other tea countries it does not occur in Ceylon tea.

R. solani usually becomes prominent just before the bushes are due for pruning, and it tends to occur periodically in the same bushes. The disease is not common and only relatively small areas of tea are affected. As the fungus feeds on dead leaves it is advisable to collect and burn those found beneath the bushes together with the prunings. A copper fungicide will kill what hyphae remain on the stems should drier conditions resulting from the removal of branches fail to do so. The real difficulty in controlling the disease is the existence of the fungus in the soil as it is likely to climb the bush again when conditions are favourable. Heavy shade should be avoided and any obstacle to free circulation of air through the bush should be removed.

Brief mention was made in Chapter III to another disease of young tea plants known as *collar rot.* This disease is characterised by a blackening of the stem for a length of about half an inch or less from ground level upwards (Plate 8, Fig. 3). The blackened region is thinner than the parts immediately above the below it. The stem above the dead area is markedly swollen when a thick callus is formed. Although the dead bark remains in position the effect is the same as "ring barking" and the consequences are the same.

This disease occurs in nurseries not efficiently shaded, and amongst plants grown from seed-at-stake as well as transplanted seedlings put out as supplies. The cause of the trouble is the overheating of exposed soil by the sun. Owing to the heat, the tissues at ground level are killed and this alone is sufficient to cause the visible damage. The damaged plants do not die immediately for reasons already explained in Chapter III. Seedlings are sometimes damaged in this way before the seed reserves are exhausted and then it is not unusual for new shoots to grow from below the ringed zone, sometimes from the seed itself. Even when new shoots are formed the original ringed stem dies. That results either from injury to the wood directly by heat, or from the clogging of the vessels by micro-organisms which enter the stem via the dead zone.

PLATE 8.

1 2 3

SEEDLING DISEASES.

1. " Bitten off " disèase due to unsuitable soil acidity.
2. Healthy seedling root system for comparison with " Bitten off."
3. Collar rot due to overheating of surface soil.

Peculiar blister-like swellings are sometimes (rarely) seen on seedling leaves. They are usually about half an inch in diameter and one-eighth inch thick and lie across the main vein near the tip of the leaf. They are quite smooth, usually yellow though sometimes white, red or green, and each results from the multiplication of the internal cells of the leaf. No fungus or other organism has been found within them and all attempts to transmit the condition to other leaves have failed. The affected leaves ultimately fall off but those developed later remain healthy.

Why these curious blister-like swellings develop occasionally on seedling leaves is unknown. Possibly they result from a temporary excessive water supply accompanied by an abnormal rise in temperature. That, however, is merely guessing and not very satisfactory conjecture either because it affords no reason why blisters are not more generally prevalent when such conditions prevail.

Since the arrival of Blister Blight in Ceylon these seedling leaf galls are sometimes sent to the Institute as abnormal examples of that disease. From the foregoing it will be seen that the origins of the two diseases are quite different.

Many other types of galls are found on tea bushes, some very large and woody, others quite small and insignificant. With one exception none is known to be infectious. That exception is the gall found on tea seedling roots. As that is caused by an animal organism, an eelworm, it will be described in a later chapter dealing with that group of animals.

LITERATURE.

Eden, T. Alkalinity of compost.—*Bull.* **19**, 59-60 (1939).

Gadd, C. H. Tea and soil acidity.—*Tea Quarterly*, **1**, 2-6; 31-35; *Tea Quarterly*, **2**, 1-6 (1926-27).

— 'Bitten off' disease of seedlings.—*Tea Quarterly*, **13**, 54-58 (1936).

— *Rhizoctonia solani*.—*Bull.* **3**, 14 (1929). *Bull.* **4**, 12 (1930).

— Seedling leaf galls.—*Bull.* **3**, 14 (1929).

CHAPTER 10.

VIRUS DISEASES.

Some of the most destructive diseases of animals and plants are caused by viruses. Hydrophobia, typhus and influenza are well known names of virus diseases affecting animals, but the names of plant virus diseases are not so well known except to growers of the affected crops, yet such names as Bunchy Top of plantains, Swollen Shoot of cocoa and a few others sometimes make headline news. Viruses are not all equally destructive. The common cold can hardly be compared with yellow fever in that respect, yet even the cold, because of its infectious nature, is a menace to the well-being of a community. One of the least destructive of plant diseases is one that occurs in tulips. Certain varieties were highly treasured because of their variegated flowers, until it was discovered that they were merely virus-diseased specimens of a self-coloured variety. That discovery placed a very different value on them, particularly when it was recognised that the disease menaced the healthy self-coloured plants.

The discovery of viruses in tea plants was a matter of considerable importance and, in view of what was known about other viruses, it aroused great interest. Before describing the disease in tea caused by viruses it will be necessary to review briefly some of the known facts about viruses and virus diseases in general.

First, what is a virus ? To a chemist it is nothing more nor less than a protein of high molecular weight but different from the life substance, protoplasm. Its individual particles are so small that they cannot be seen even with the aid of a powerful microscope, but they are able to increase in number like living organisms. Although not literally true, a virus may be regarded, for practical purposes, as a living organism, too small to be seen.

Some of the smallest organisms are bacteria, commonly known as germs. Individually they cannot be seen with the naked eye but when placed on a food surface they increase in number to form a colony, easily visible. The growth of a virus by increase in number of particles and not in particle size is somewhat similar, except that

PLATE 9.

1 2 3

PHLOEM NECROSIS.

1. Curled leaves.
2. Branch showing apparently healthy growth above necrotic leaves.
3. Zig-zig stems

it never occurs, so far as is known, outside a living cell. Growth occurs only *within living cells;* so, all known viruses must be regarded as obligate parasites.

Another important character is their great capacity for variation. Every year new virus diseases are recorded, and although their origin cannot always be traced it is certain that some of the new diseases are merely different manifestations of previously known viruses. In one host a virus may be non-virulent and cause little damage, whereas in another the same virus will be virulent and may cause different symptoms. This capacity for variation, this ability to adapt themselves to new hosts and create different types of damage, makes them the greatest menace to both animal and plant life.

As a virus cannot be seen its existence becomes known by what it does, by its effect on the animal or plant it inhabits. Each virus is recognised by the symptoms it causes. A virus disease differs from other diseases with which no visible organism is associated, e.g. 'Bitten off', sun scorch, etc. by its infectious nature. It can be transmitted to healthy plants at will, by means of sap from a similar but diseased plant. Before a pathologist will state that a disease is caused by a virus he will first satisfy himself that the proof of transmission is complete. A disease which can be transmitted in the manner to be described hereafter cannot possibly result from old age, malnutrition and other similar causes as is sometimes suggested.

Virus diseases of plants can be transmitted in three main ways. The first and simplest is by the introduction of sap from a diseased plant into a healthy plant by means of needle pricks or other minute wounds. Viruses, transmissible in this way, are often carried from plant to plant unwittingly by the grower. The mere handling of a diseased plant will leave sufficient sap on the fingers to cause infection of a healthy plant handled later. The necessary wounds are made by the breaking of fragile hairs on the leaves or stems.

Some viruses can be transmitted by some sucking insects, termed vectors, in much the same way as malaria is carried by specific mosquitoes. The insect vector having fed on a diseased plant later carries the virus to other plants when feeding. The virus is injected into the plants through the needle-like mouth parts, with saliva.

Some viruses cannot be transmitted directly, nor by insects unless the correct vectors are known. Then grafting methods have to be tried. When suitable pieces of diseased plants (scions) are grafted on to healthy plants (stocks), the stocks later exhibit the

same symptoms of disease when a virus is the cause, but not otherwise. The graft can of course be made the other way round, a healthy shoot being used as the scion and a diseased plant as stock; then the disease must occur later in the scion.

Transmission experiments demonstrate other matters of interest regarding virus. Although a minute quantity of sap may be used to cause infection, a very large quantity, equally infectious, can be obtained from the infected plant later. Also, though the virus may be introduced into one leaf it can later be obtained from others, as well as from the stems and roots. These facts demonstrate the ability of a virus to grow within a plant and to move freely from one part to another. A virus, however, does not as a general rule move into the seeds.

Because a virus permeates the whole plant, destruction of the whole plant is essential if the virus is to be eradicated. The removal of those parts only which exhibit the symptoms can do no good, as new growth is immediately infected with the virus from the apparently healthy stems or roots.

All plants have a natural ability to resist invasion by virus, somewhat similar to their resistance against fungi. As certain fungi are able to overcome that resistance, so can specific viruses break down that defence. A plant may be completely immune to many viruses, yet be very susceptible to another. Moreover, the extent of this power of resistance against a specific virus varies considerably between individuals of the same species. One variety may be highly resistant and another very susceptible to the same virus. No explanation can be given of the way in which resistance is offered nor can any reason be given for the observed variation.

If resistance is defined as an ability to prevent the multiplication of virus particles within the body, some plants, although they appear perfectly healthy after being infected with a specific virus, cannot be described as truly resistant when it can be shown that the virus has grown within them though no external evidence of its presence can be seen. Such plants are termed *Symptomless carriers*. Their existence can be demonstrated in ways such as the following. A diseased scion is grafted on a healthy stock, yet the stock remains healthy as none of the expected symptoms develop. The stock then appears to be resistant. When another graft is made on the same stock, this time using a healthy scion, and that scion later exhibits the correct symptom of the disease, it becomes evident that the apparently resistant stock, showing no symptoms, did in fact carry the virus. The stock is therefore demonstrated to be a symptomless carrier.

One other subject requires brief mention. Animals on recovery from a virus disease are found to acquire a resistance against that particular virus which they did not possess previously. In some cases that *acquired immunity* persists for a short time only; in others it remains longer, even for the rest of the animal's life. Its duration depends entirely upon the kind of virus and not on the severity of the disease experienced. The medical profession makes great use of this ability to acquire immunity, and has devised means of inducing that protection artificially by inoculation. In this way men and domestic animals can be protected against many diseases. Acquired immunity in plants, however, is practically unknown, mainly because plants rarely, if ever, recover from a virus disease. They have no ability, such as animals have, to fight and destroy invading organisms and viruses. The acquisition of immunity, whether it is the result of natural infection or inoculation, depends upon and results from that fight. Plants, having no means to fight in that way, cannot acquire immunity.

While on this subject it may be well to clear away certain misunderstandings regarding 'cures' in plants. A plant is never cured of a disease in the sense that an animal is. When an animal's body is invaded by a parasite an immediate struggle begins. At first the invader may gain the upper-hand and the animal becomes sick and exhibits the symptoms of a particular disease. But the fight goes on. The animal may receive assistance, additional weapons in the form of drugs, and ultimately may achieve complete victory and annihilation of the enemy. There may be scars resulting from the battle but the animal is cured. But when a plant is invaded by a parasite there is no apparent battle and the invader is never destroyed.

A fungus which invades a leaf or other plant organ invariably kills some of the tissues and that damage cannot be repaired. Further growth of the fungus, in some cases, may be stopped as though by a barrier. The extent of the damage may then be small as with leaf spots, but there is no evidence of a direct attack on the invader such as occurs in animals. A plant may drop its leaves and so get rid of the parasite which has invaded them. In that sense the plant may be said to be 'cured' though almost leafless, if a change in climatic conditions prevents the parasite attacking the new leaves as they develop. A plant cannot drop its diseased stems and roots, but they can be removed with a knife. What cures are effected in plants resemble those of a surgeon, not of a physician. Appendicitis may be 'cured' by a surgical operation, but the more general use of the word cure implies a recovery without the aid of a knife

or the removal of a diseased organ. In that sense plant diseases are not curable. In this connection it should be noted that a plant can replace an organ, but cannot repair it. Animals normally cannot replace organs and that perhaps is one reason why direct measures for their defence have to be taken immediately against invaders. Although plants cannot be cured they can be protected by poisonous sprays and other means. Such measures prevent disease, by killing or warding off the parasites, but do not cure the plant should it become infected.

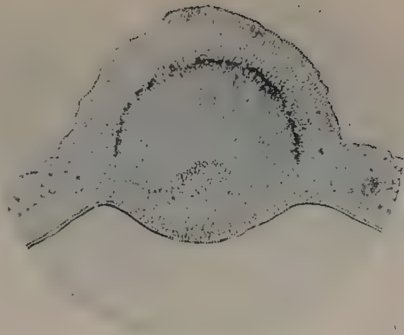
The discovery of a virus in tea brought into the open an enemy which had lain hidden for many years. Affected bushes had been regarded merely as unproductive ; their gradual degeneration was considered to be the result of continued growth at a high elevation or other similar natural cause. The disease has no very striking character, nothing to attract attention and to suggest that an active parasite is operating in the fields.

The earliest symptom to be recognised was the occurrence of dead zones within the bark of the main roots. Externally, the roots appear normal, but when the bark is shaved away dead zones can be found near the cambium. As the tissue affected is the phloem, through which elaborated foods are passed, the disease was named *Phloem necrosis.* No visible organism is to be found in the tissue.

Cuttings from diseased bushes when rooted and grown in other soils at a lower elevation were found to give rise invariably to diseased plants, though cuttings from healthy bushes grew normally when planted in the same soils. These observations cleared up several points. They showed that the disease did not result from a deleterious substance in the soil or from the lack of an essential nutrient element. Nor could the disease be due to old age or too high an elevation. Such results would be expected if a virus was concerned, but they could not be accepted as proof that the disease did in fact result from virus. That proof was provided by grafting experiments in which healthy plants became diseased after diseased scions were united with them. Phloem necrosis was then known to be caused by a virus.

Meanwhile a search was made for other characters by which the disease could be recognised more easily. Soon it was ascertained that the necrosis of the phloem is not restricted to the roots ; it occurs in stems and leaves. The necrosis is not continuous ; it occurs here and there as small patches in the tissues. The most convenient part to examine is the petiole (short stalk) of the leaves, where the necrosis occurs in the position shown Fig. 1 of Plate 10. The section illustrated is much magnified, but with experience the

PLATE 10.



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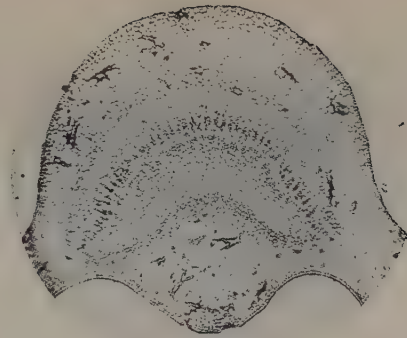

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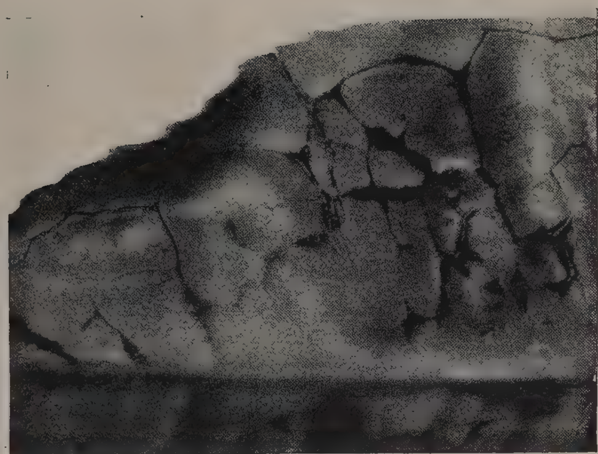

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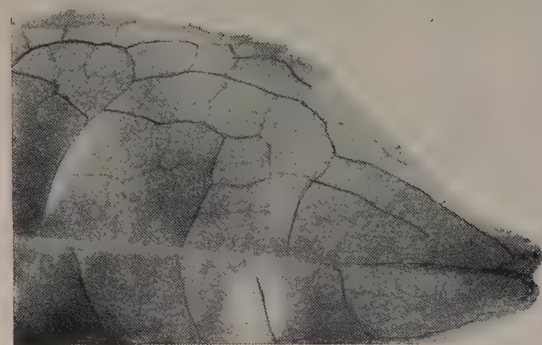

4

PHLOEM NECROSIS

1. Section through petiole of diseased leaf showing the position of the necrotic phloem.
2. Section through petiole of healthy leaf. 3. Necrosis along the leaf-veins (unusual.) 4. Healthy leaf for comparison with Fig. 3

necrosis can be seen in a freshly cut petiole with the unaided eye. The appearance of a healthy petiole is also shown for comparison (Fig. 2). The necrosis will not be found in every petiole of a diseased bush, except when the disease is very severe.

There are other symptoms more easily recognised by a planter. The commonest is a backward arching of the leaves often accompanied by an inward folding of the leaf blade, resembling the partial closing of a book. Another, though less frequently encountered, is a zig-zag habit of growth in the young stems (Plate 9, Fig. 3). Sometimes, though very rarely, a necrosis can be seen along many of the leaf veins (Plate 10, Fig. 3). These symptoms are accompanied by a dwarfing of the leaves. Another symptom was observed for the first time in 1948. Some of the leaves turn over, so that the upper side of the leaf becomes the lower. This peculiar turn is frequently accompanied by a necrosis of a part of the leaf blade, visible as definite dead patches.

Although the typical forms of curling (Plate 9, Fig. 1), zig-zag and dwarfing are not likely to be confused with somewhat similar conditions in healthy plants, it should be understood that they are not of themselves diagnostic. The real diagnostic character is a necrosis of the phloem. When the disease is suspected because of these or other symptoms, specimens exhibiting the suspected character should be sent to the Institute for examination and a pathologist's opinion obtained.

Every degree of resistance between marked susceptibility and apparent immunity is to be found. The markedly susceptible bushes are easily recognised by their poor growth, dwarfed and curled leaves and general unproductive condition. Whether completely resistant bushes exist is open to doubt, though symptomless carriers are known A bush which exhibits no symptom of the disease may be healthy because the virus has never reached it; it may be healthy because the virus has failed to establish itself and multiply within the bush (true resistance) or the bush may appear healthy although the virus exists in it (carrier). Into which category an apparently healthy bush should be placed cannot easily be determined. Repeated observations over several years show that the number of diseased bushes in defined areas steadily increases, even when the incidence of disease is initially high. The percentage of truly resistant bushes (if any) and symptomless carriers together must therefore be small. Many bushes have a high power of resistance and, though positive symptoms may be detected, the bushes show little or no resulting deterioration.

That severely necrotic bushes are almost entirely unproductive can hardly be questioned. They produce only dwarfed, curled leaf and very little flush suitable for plucking. The time taken for a bush to reach such a condition is unknown. Some bushes probably reach it more rapidly than others, and some diseased bushes may never reach it. The general rate of deterioration, however, must be extremely slow as it is difficult to demonstrate that the disease results in a gradual decrease in crop.

How the virus is transmitted from bush to bush in the field is unknown. The disease cannot be transmitted experimentally by plucking or pruning, or by placing pulped tissues from diseased bushes into wounds. If the disease is disseminated by insects nothing is known regarding the vector, as all experiments with insects, so far, have failed. Field observations indicate that the spread of infection is mainly from one bush to its immediate neighbours, rather like that of a fungus root disease. That suggests a possibility of the virus being carried in some way from bush to bush mainly below ground. Dissemination, however, cannot be entirely below ground (if at all), otherwise the occurrence of solitary diseased and small groups of infected bushes widely separated cannot be accounted for satisfactorily. The virus can be transmitted by grafting, but as root fusions in the field are uncommon some other means of transmission must occur in nature. Many guesses have been made but none has proved correct when tested experimentally.

The disease is essentially one of up-country bushes as, with very few exceptions, it is unknown below 4,000 ft. At the highest elevations the symptoms are most marked and deterioration most rapid. The severity of the disease appears to be related directly to height above sea level. The reason of this is most probably the difference in average temperature at the different levels. The symptoms of several virus diseases become masked, i.e. are not exhibited when the infected plants are submitted to high temperatures. That the symptoms of Phloem necrosis are masked at higher temperatures has not been proved experimentally, but field evidence strongly suggests the probability. If so, the possibility that the virus may exist in tea bushes below 4,000 ft. though the disease is unknown there, must not be overlooked.

The masking of symptoms occurs at times even at the highest altitudes. During periods of rapid growth the new growth in markedly diseased bushes appears to be normal and healthy as though the bush had recovered (Plate 9, Fig. 2). The apparent recovery is, however, very temporary, as later the necrosis can be found in what was apparently healthy growth. The reason for this

PLATE 11.

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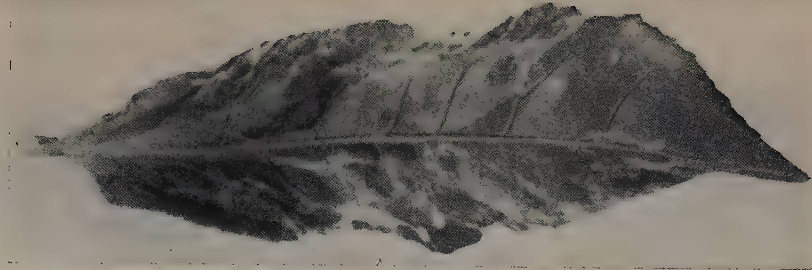

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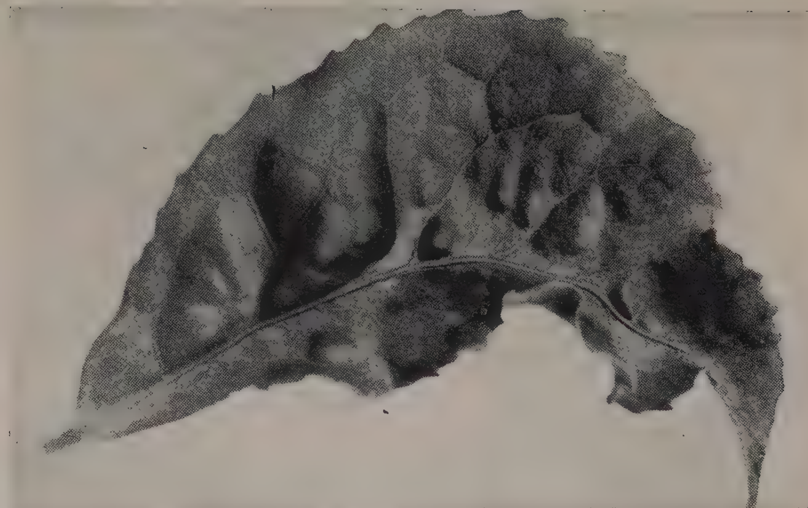


3

INFECTIOUS CHLOROSIS.

1. Seedling to which the virus from 'infectious chlorosis' has been transmitted by grafting.
2. Variegated leaf (infectious.)
3. Distorted leaf accompanying 'infectious chlorosis'.

apparent temporary recovery is probably that the symptoms were masked by the warmer conditions that encouraged the vigorous growth. There is, however, another possible explanation. The rate of growth of the tea virus and its spread through the bush is relatively slow when compared with other viruses, so it may be possible for a shoot temporarily to outgrow the virus. Whatever may be the correct explanation the apparent 'cure' is very temporary. The slow movement of the virus in tea is known from the time necessary to obtain positive results in grafting experiments. Occasionally, bushes are seen with marked symptoms in some branches while other appear healthly.

As no form of cure for a virus disease of plants is known the only rational method of control is by destroying the virus, which entails the destruction of every plant that contains it. Such a drastic method, though essential against some diseases, appears unwarranted for tea. Although the tea virus is a potential threat to the tea industry it is not an active or absolute one. If tea bushes were to be destroyed on this account many fields would have to be completely uprooted as seventy per cent or more of the bushes are known to be infected. Under present circumstances no estate owner would seriously consider treatment on such a scale for so little apparent reason.

The only treatment recommended is the removal of all bushes as soon as their productivity falls below an economic level. In areas where the disease is prevalent, ninety nine per cent of the non-productive bushes are infected and so there is no necessity for a planter to become expert in diagnosis. The non-productive condition of the bush is sufficient reason for its removal.

The best time to diagnose Phloem necrosis is when the bushes are recovering from pruning because leaf curl is most prominent then. But the best time to determine whether bushes are non-productive is towards the end of the plucking cycle. Bushes for removal should therefore be marked before, and not after pruning as is sometimes done.

For replacements, the best planting material will be cuttings from the most resistant types. There is no means of determining whether a healthy bush is resistant or not by eye. The mother bushes should therefore be selected in fields known to be severely infected

As yet only one virus disease of tea has been described. Whether that disease, Phloem necrosis, results from a single virus or a mixture is not known. As already stated the symptoms are not

constant except for the necrosis of the phloem and possibly the leaf curl. Occasionally new symptoms occur, e.g. the leaf turnover first observed in 1948, and the question arises whether the new symptom is indicative of another virus or a variant of a known one. Viruses are known to have a great capacity for variation and new symptoms may result from such variation. They may equally result from an addition to or change in an existing complex.

Other viruses may occur in tea though nothing is known of them. For instance a few years ago a bush with a very unusual type of variegated leaf was observed on the Institute's property. The leaves were streaked with white (Plate 11 Fig. 2 and 3). The condition proved to be transmissible on grafting (Plate 11, Fig. 1). There was no necrosis of the phloem and no other sympton suggested any relationship to the virus of Phloem necrosis. The bush and infected experimental plants were destroyed, and so far no other case has been seen or reported. This case is mentioned merely to show the probability of other viruses being found in tea or of changes occurring in the known virus or virus complex. Any new symptoms observed should be reported to the Institute immediately.

LITERATURE.

Bond, T. E. T. Plant viruses and virus diseases.—*Tea Quarterly*, **17**, 12-17 (1944).

— Phloem necrosis.—*Bull.* **22**, 39-42 (1941). *Bull.* **23**, 34-42 (1942), *Bull.* **24**, 25-31 (1943), *Bull.* **25**, 27-31 (1944), *Bull.* **26**, 28-30 (1945).

Gadd, C. H. Disease in non-productive bushes.—*Tea Quarterly*, **12**, 75-85 (1939).

— A virus disease of tea.—*Tea Quarterly*, **12**, 110-130 (1939).

CHAPTER 11.

NEMATODES.

Amongst the great variety of minute animals that inhabit soil is a group of worms known as Nematodes. They resemble eels, both in shape and movement, more than the earthworm, and because of this resemblance they are popularly known as *eelworms*. While in the soil they are difficult to perceive, though when removed, many species can be seen easily with the unaided eye. Some are saprophytes and others are parasitic in animals and plants.

If the group was primarily saprophytic, the evolution of the parasitic habit has been accompanied by structural changes in the body, particularly the mouth. Most saprophytic species, having no hard structure in their mouths, can feed only on small particles, often bacteria, and very soft foods, and so are quite incapable of causing direct damage to animals or plants. Others have a hard needle-like structure termed a spear which can be protruded and withdrawn at will. The spear is hollow and attached to the gut in such a way that food has to be drawn into it through the hollow tube. The development of this structure probably made normal feeding more difficult, but it provided the worms with an offensive weapon. During their travels through the soil they frequently bump into other small soft-bodied animals, then with a quick thrust, the sharp spear is forced into the obstructing body and body-fluids extracted by sucking. Many species, armed in this way have become predatory on other eelworms, soil insects and other soft-bodied creatures. They do not appear to hunt particular prey but get a meal from any suitable body they happen to encounter. Other predatory species have entirely different mouth structures which assist them to swallow their prey, usually other nematodes, whole.

To be parasitic on plants a nematode must have a particularly strong spear in order to penetrate the hard cell wall and reach the sap within. Because of the increasing hardness of plant cell-walls with age, plant parasitic eelworms usually attack the youngest part of a root, just behind its tip where the cell walls are thinnest. It would not appear necessary for an eelworm with a strong spear to do more than thrust it into a root in order to obtain food. Some eelworms get their food in that way, and one such species (Hoplolaimus sp.) is known to feed on Dadap roots. The worms are found on the surface of the roots yet are firmly attached by their spears which are thrust into the root tissues. They un-

doubtedly suck the juices from the roots and cause minute wounds. These worms when prevalent on dadap roots have not been found attached to nearby tea roots.

Two species which are important parasites of tea do more than feed at the root surface. With the spear they make a hole sufficiently large to squeeze the body through, and then live and feed entirely within the root. This gives them a further advantage as they are protected from enemies, such as the predatory species, while in a root.

The best known plant parasitic nematode is probably *Heterodera marioni* (Cornu) Goodey, the Root-knot eelworm, as it inhabits tropical and temperate soils and lives in the roots of many hundreds of plant species. To tea planters it is well known as a pest of Dadaps, Tephrosia and Tea seedlings (Plate 12).

Its eggs are usually extruded from the infested plant as a gelatinous mass containing several hundred eggs. They hatch in the soil about four or five days after extrusion. From each egg emerges a larval worm, resembling a microscopic eel. The young worms immediately move towards the tip of any root growing in their vicinity (Plate 13, C) or to be damaged region of the root where their mothers lived. They are attracted by an exudation from a growing root which they can perceive some distance away. Having reached a root tip they proceed to bore into it and if, for them, it is the right sort of root the females settle down to spend the rest of their lives there. The sex of the larval worms cannot be determined, but as they reach maturity the two sexes develop very differently. The male increases in size but retains its eel-like shape and ability to move about. He is usually to be found in the soil and damaged parts of the infested roots. His services are not essential as females can produce their young parthenogenetically, i.e. without the intervention of males.

The female becomes pear shaped, the narrow end being the head. She becomes incapable of movement and must feed where she lies embedded in the root (Plate 13 D and E). Her saliva stimulates the root cells in her immediate vicinity to enlarge and divide. The result of this abnormal growth can be seen as a small swelling or gall on the root, known as a root-knot. A view has been put forward that the eelworm can survive only in roots which react in this way to the saliva ; if the root sap counteracts the saliva action, the cells do not enlarge and the young worms then leave the root. Be that as it may, infested roots can always be recognised by the root-knots resulting from the eelworm attack.

PLATE 12.

1 2 3

ROOT KNOT EELWORM (HETERODERA MARIONI).

1. Root-knot on *Tephrosia vogelii* roots.
2. Root-knot on tea seedlings.
3. Tea root from a mature tea bush infested with the root knot eelworm.

has an effect on the eelworm population, ultimately preventing further increase. A rough balance between plant growth and eelworm attack is finally reached. For this reason eelworms rarely kill mature plants though their vitality is seriously reduced.

Plants may have their roots heavily infested by the root-knot eelworm without giving clear indication, above ground, that anything is amiss. That is often the case with *Tephrosia vogelii*, grown as green manure. In actual fact, as might be expected, the growth is not really as good as it would be were the roots not infested, but the difference is difficult to estimate, except when infested and non-infested plants are grown alongside, as in pots. The first clear indication of something being wrong is when the Tephrosia plants are lopped. A large proportion of the plants then die unexpectedly, for the reason that the food which should have gone into reserve has been used by the eelworms. Also the new roots which should supply the new shoots are unable to get a fair start because of eelworm invasion as soon as they start to grow.

When a dadap tree is attacked it continues to grow apparently normally at first. Meanwhile the eelworm population increases rapidly — a new generation every month some hundred times bigger than the old. In time the formation of roots cannot keep pace with their destruction and the water supply to the leaves is gradually reduced. The tree gradually accommodates itself to the decreasing water supply by producing fewer leaves and shorter stems. i.e. by less growth. The leaves often become somewhat yellow and are more crowded on the stems as the latter do not extend fully. This gradual slowing down of growth becomes apparent by the gradual decrease in the amount of green stuff obtainable as loppings, until finally the tree becomes almost valueless as a source of green manure. Replacement of trees in infested areas is practically impossible as the young plants or cuttings cannot produce enough roots, fast enough, to obtain a good start. One method by which their start can be somewhat improved is by putting a large quantity of green material in the holes, to rot before the dadaps are planted. During the rotting process the population of parasitic worms is reduced by the activities of predatory eelworms and certain fungi which are also parasitic on nematodes. The advantage gained, however, proves only temporary.

The root knot eelworm is a serious pest when it occurs in tea nurseries. The plants become unthrifty and stunted. Viewed from above ground they somewhat resemble seedlings with "bitten off"

disease and for much the same reason — lack of roots. When lifted from the soil the much damaged root system indicates the cause of the disease. The tap root is swollen, short and rotted, and there are few other roots, all badly damaged (Plate 12, Fig. 2). The infested plants are valueless as supplies and should on no account be planted in the fields even though they may be only mildly affected.

The behaviour of the root knot eelworm in tea is somewhat peculiar. Though it causes great damage to tea seedlings it is normally harmless to older plants and mature bushes. Many tea fields are very heavily infested by this eelworm as is shown by the large galls formed on Tephrosia and other plants intergrown with tea. Yet the tea bushes are, as a rule, apparently free from the pest. There is evidence that although the larvae enter the young roots of mature bushes they do not remain there. No galls are formed and there is no outward sign that eelworms have even entered them. That is the normal position ; but in a few areas at high elevations something very different happens.

The larvae enter the roots and continue with their normal life cycle. The roots become thickened and assume rather irregular shapes (Plate 12, Fig. 3). Minute holes can be seen where eggs have been extruded and through which young larvae probably re-enter the root. The infested bushes usually have a "thin" appearance, but they are most easily detected after pruning as recovery is markedly delayed.

At first it may appear that the eelworm in mature tea bushes is not the same as that found in Tephrosia, but the opinion of experts on the group is that both nematodes are the same species, *Heterodera marioni.* There must therefore, be at least two races of this species, one which can infest adult tea roots and another which cannot. If, as seems probable, the one race has sprung from the other it is also probable that the new race is that which infests adult roots.

That supposition raises a rather important question. If the eelworm in some localities has become adapted to live in adult tea roots, is it not likely that others elsewhere may become similarly altered ? The only answer can be "Possibly," though there is no evidence of such a change in the last twenty years or more. It also raises a subject of some practical importance.

In many fields *Tephrosia vogelii* was grown almost continuously because it was one of the best green manure plants. The result has been that the soil throughout the fields is heavily infested by the

root-knot eelworm. Dadaps cannot now be grown in those areas, yet the tea has not been affected. To grow the same crop repeatedly, without change, on the same ground is not a sound agricultural practice. Tephrosia should be alternated with other green manure plants such as Crotalaria which are not infested by the eelworm. By doing so the eelworm population is not maintained at a high level continuously.

Another eelworm which infests tea roots is *Pratylenchus (Anguillulina) pratensis* (de Man) Filipjev, known as the Meadow eelworm because it was earlier found to infest grass roots. It occurs in patna grasses and it is possible that it reached tea from that source. It differs from the root knot eelworm in several respects. e.g. its habits are different and it never causes galls on infested roots.

Both male and female retain an eel-like shape throughout their lives, and both larvae and adults, but not eggs, can usually be found in large numbers around infested roots. Like root-knot eelworms, they are attracted to the root tips and enter the root in that region. Though their movements inside the roots are somewhat restricted they can move from cell to cell by boring a passage.

When for any reason they dislike the conditions within a root they tend to wander somewhat before leaving it. Sometimes, when the eelworm is gravid a few eggs are left in the root, affording evidence of her entry and departure. In tea roots the worms do not move far and the eggs lie in close proximity to the females. Unlike *Heterodera, Pratylenchus* lays her eggs singly, and not more than one or two fully developed eggs can be seen in the body at any one time. She may deposit one or two a day for about four weeks. The eggs hatch within the roots in from 15 to 17 days. The larvae become adult when about a fortnight old, but the females do not begin to lay eggs till a fortnight later. The life cycle, from egg to egg occupies about seven weeks.

The damage to the bush is much the same as that caused by the root knot eelworms except that the roots are never galled. Infested feeding roots can usually be detected by the presence of small black spots on the otherwise white surface. The spots are due to dead discoloured cells where worms have entered. The worms carry on their bodies numerous germs which could not otherwise enter an undamaged root, and these, possibly more than the eelworms themselves, hasten the death and decay of the roots.

As meadow eelworms cannot feed in a dead root, they leave it to search for other living ones. This accounts at least in part

for the presence of numerous worms free in the soil. They may leave living roots for other reasons as for instance when infested roots are left immersed in water.

There is no sure method of determining whether the condition of unthrifty bushes is due to the meadow eelworm or not except by locating and identifying the nematode. The affected bushes occur as large patches though they are not all in equally poor condition. Some, relatively few, may appear quite healthy and vigorous. When a bush is uprooted the absence of bunches of feeding roots should arouse suspicion. If the roots are heavily infested some of the main roots which appear normally healthy, will show dead areas of various sizes when the surface is scraped. The bark in these regions is dead right through to the wood, and when it is cut out numerous worms will be found on the surfaces of the wood and bark at the edge of the dead patch These lesions cannot vitally affect the bush though they afford a ready means of collecting the worms for identification.

So far as can be determined experimentally the meadow eelworm is incapable of boring into the bark of thick roots; it can enter the zone just behind the root tip only. Colonies found beneath the bark must have persisted there from the time that region was young, and the position of dead lesions in old thick roots affords a rough indication of the time the bushes have been infested. As many bushes have lesions near the base of the tap root they must have first been invaded when seedlings, though the bushes grew apparently normally for many years before the deterioration became noticeable. In general the deterioration of bushes is extremely slow; at times the condition of infested bushes seems to improve and at others to deteriorate rather rapidly.

As both root-knot and meadow eelworms live within roots the only way to kill them in such sites is by destroying the infested plants. That is practicable when the plants are annuals; the root remains can be destroyed after the crop is harvested. If then no susceptible crop is grown on the soil for several years the greater part of the soil population will die, and a susceptible crop can again be grown with fair prospects of obtaining an economic harvest. Although the susceptible crop plants may not be free of eelworm damage its extent will be relatively small. Crop rotation is one of the best methods of combatting eelworm pests in annuals.

Tea, however, is a permanent crop plant. Infested bushes would possibly be uprooted and burnt when observed, if there were sure means of destroying all the eelworms remaining in the soil. A

reduction in eelworm number is not enough, even though large. One hundred per cent kill is required, and that is practically impossible to achieve on a field scale. If only a few eelworms remain in the soil after treatment it can only be a matter of time before a very large population is again built up, and the newly planted bushes become heavily infested.

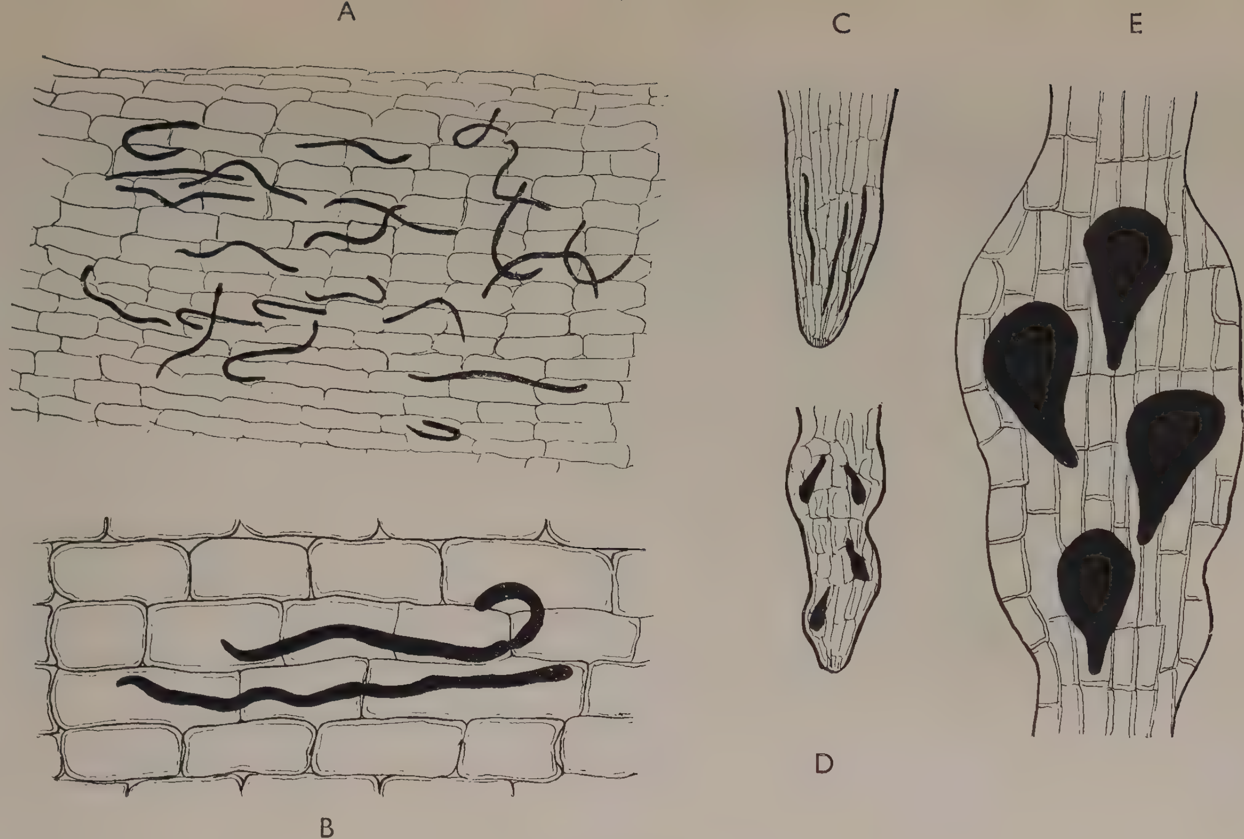
Several methods of soil sterilisation are known but none has proved really efficient against eelworm in the fields. They are fully efficient when relatively small volumes of soil have to be sterilised, particularly when the soil can be enclosed, as in a box. They are often of value for garden beds, where rotation can also be practised, but even for tea nursery soils their value is somewhat doubtful if all risk is to be avoided.

Recently a new soil fumigant has been put on the market under the abbreviated name DD (not to be confused with DDT) which appears to offer better prospects of success. It is most efficient when the soil has a fine tilth such as is obtained in gardens and nurseries, and least efficient when the soil is lumpy and contains clods as is usually the case in fields. DD and other soil fumigants are most valuable for the pretreatment of soil to be filled into baskets, but none should be used after the land is planted.

Fallowing before replanting has much the same objections as field soil sterilisation. There can be no certainty that all the eelworms have died even after several years. During the fallow, the land must be kept clear of all weeds as some would almost certainly be alternative hosts on which the worms could survive.

Mention has been made of the existence of apparently healthy bushes growing in soil heavily infested by the meadow eelworm. Their presence suggests a form of resistance somewhat similar to that normally exhibited by adult bushes against the root knot eelworm. Resistance of this type has been observed in roots of several species of *Crotalaria* and *Desmodium gyroides,* into which the meadow eelworm bores and leaves again without doing serious damage. Resistance against eelworms is, therefore, not a form of barrier preventing entry, but an unknown character of the sap which makes the roots distasteful. That there is great variety in tea saps is known from factory results. Differences can be detected between bushes as well as between seasons. It is not improbable, therefore, that amongst the great variety some are distasteful to the meadow eelworm. If such exist they are most likely to be found

PLATE 13.



TEA ROOT EELWORMS.

A. & B. *Pratylenchus pratensis.* within rootlets.
C. *Heterodera marioni.* Early infection at root tip by larvae.
D. & E. *Heterodera marioni.* Development of female and swelling of rootlet

in the more vigorous bushes growing in infested fields. This suggests a possible means of control which in the absence of more satisfactory methods is worthy of trial. The most vigorous bushes in infested fields should be propagated vegetatively for the production of supplies for infested areas.

LITERATURE

Gadd, C. H. A nematode disease of dadaps.—*Tea Quarterly*, **1**, 39-44 (1928).

— Root knot disease of Tephrosia.—*Tea Quarterly*, **10**, 183-187 (1937).

— A destructive root disease of Tea (*Anguillulina pratensis*).—*Tea Quarterly*, **12**, 131-139 (1939).

— Eelworm in old tea. *Heterodera marioni*.—*Bull.* **19**, 31, (1939).

— Eelworm starvation.—*Bull.* **23**, 27-33 (1942).

— *Anguillulina* in patnas.—*Bull.* **24**, 23-25 (1943).

— Parasites of Dadap.—*Bull.* **25**, 26 (1944).

— Susceptibility of tea plants.—*Bull.* **26**, 23-25 (1945).

— Eelworm populations.—*Bull.* **27**, 27-29 (1946).

Gadd, C. H. and Loos, C.A. The problem of nematode control in tea plantations.—*Tea Quarterly*, **18**, 3-11 (1946).

CHAPTER 12.

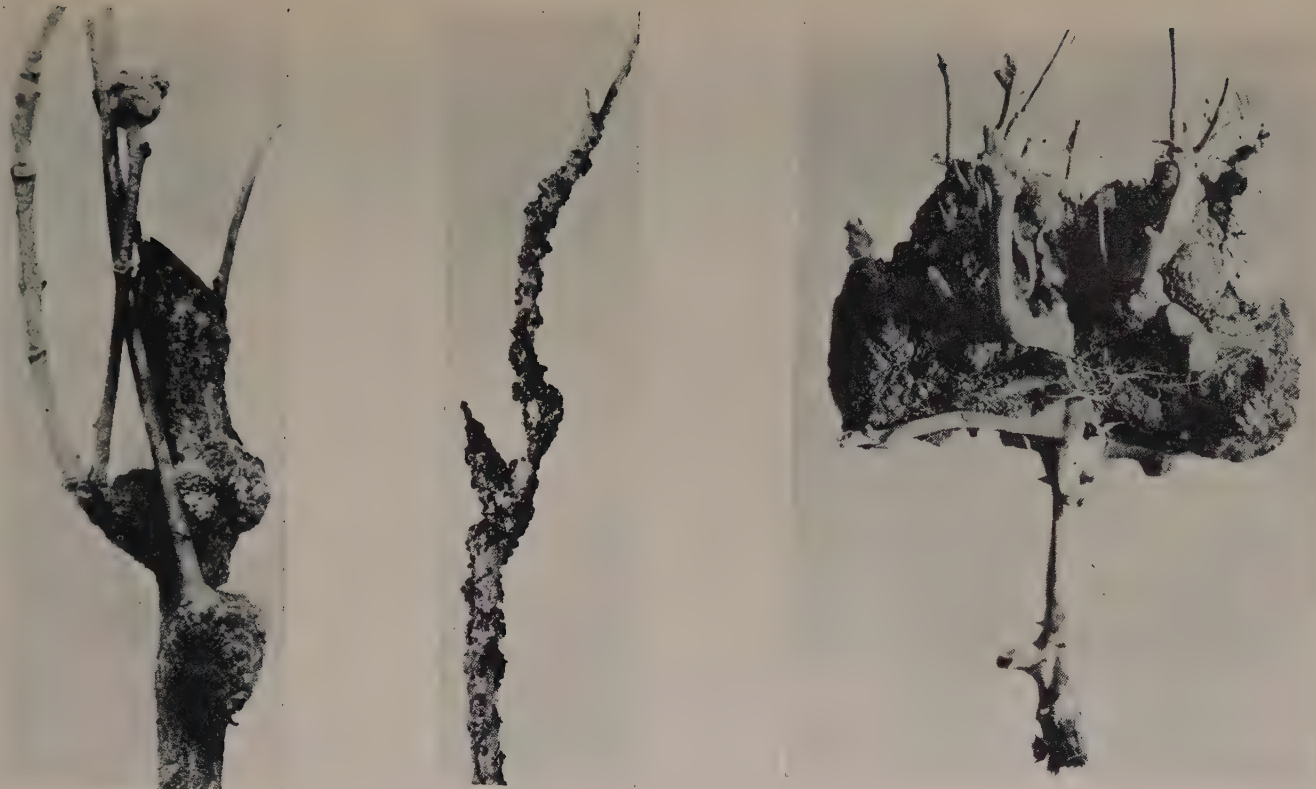
MISCELLANY.

Many fungi are parasitic on insects, and those belonging to the genus *Septobasidium* are amongst the most interesting. Several species are known in Ceylon and as they sometimes occasion alarm, by covering tea stems with a rather thick growth, a short account of them may be of interest. In Northern India one species known as Velvet Blight is said to cause considerable damage to tea, but that does not tally with Ceylon experience. The species usually seen on bushes in Ceylon is *Septobasidium rimulosum* Petch and Couch. It may extend for several feet along stems covering them with a brown or purple-black growth with slate-coloured edges. The growth has a somewhat smooth, compact outer surface, often badly cracked, and is rather woolly within (Plate 15, Fig. 3). Like many other species of *Septobasidium* it is parasitic on scale insects.

Some species of scale insects, e.g. *Chionaspis biclavis*, feed on tea stems by sucking the sap. Their mouth parts resemble a long thread which is forced deeply into the bark till it reaches the phloem. Their soft bodies are covered by a hard scale which enlarges as the body grows. They move about while young, but after starting to feed they remain stationary, each with its long thread-like proboscis deep in the bark and acting as an anchor as well as a feeding tube.

The fungus *Septobasidium* grows around and over the scales to form a rather peculiar and complicated structure, somewhat resembling a flat roofed building. It is composed of two layers. The upper which forms the roof is supported by columns or ridges of looser texture, arranged in such a way as to form a labyrinth of chambers or tunnels. Each chamber usually contains one or more scale insects. The lower layer, the floor of the building, is usually thin, often non-existent beneath the insects. Hyphae are firmly attached to the top of the scales but not to the stem as they do not penetrate the bark ; so the whole structure is anchored to the stem by the insect's mouth parts. Not all the scales within the fungus are parasitised ; some continue to live and breed normally. When

PLATE 14.



1 2 3

GALLS AND BURRS.

1. Small burrs at the bases of branches. Note also one at the apex of a cut shoot.
2. Numerous small galls on tea branch.
3. Large burr on tea stem.

an insect is parasitised special hyphae enter its body, yet it continues to feed for a time but does not breed. Ultimately the insect becomes embedded in fungus and is then not easy to find. The young, from non-parasitised scale insects, sometimes escape but they invariably carry the fungus spores on their bodies and later become imprisoned and parasitised when the fungus spores germinate.

It will be evident from this short account that, although the fungus takes nothing directly frcm the bush, it gets its food indirectly from that source, via the insects. Also the apparent damage, sometimes reported, is most likely the direct result of the insects feeding. On the whole, although the fungus destroys many scale insects, it gives little or no benefit to the planter and is therefore best removed. It may easily be removed with a hard brush, such as can be made from a piece of coconut husk. The brush should be applied with sufficient pressure to remove and kill the scales at the same time.

Another fungus which attracts much attention, though it is relatively harmless to the bush, is known as Sooty Mould *(Meliola* sp.). The leaves are covered partially or entirely, by a black film with a more or less powdery appearance. The film can be rubbed off the leaf quite easily and then the normal green undamaged surface again becomes visible. Usually the leaf is undamaged, but the film prevents the sunlight reaching it and to that extent the fungus is harmful. When dry, the black sheet cracks and later flakes or peels off the leaf.

The fungus feeds on the secretions (honey dew) of insects, usually aphids or scale insects, living in the bush itself or, more frequently, in shade trees overhanging the bush. Honey dew is a somewhat sugary, almost colourless, secretion much beloved by ants ; they may often be seen stroking aphids (black or green-fly) to induce them to secrete the fluid. Where it falls on a leaf a somewhat sticky patch is formed on which, if a spore finds lodgment there, a sooty mould grows.

Sooty mould is most prevalent during dry weather when the insects abound, and especially, when Gliricidia trees form the shade. Then, nearly all the foliage of bushes below the Gliricidias is blackened by the fungus, and that sometimes occasions alarm. The remedy is to get rid of the insects by spraying or lopping.

Another fungus sometimes mistaken for a parasite is Horse-Hair Blight (*Marasmius equicrinis* Mull.). Its name is so apt and descriptive that the fungus cannot be mistaken for any other blight.

Its mycelium takes the shape of thin cords, black, round and shining, like black horse-hair. The threads are attached to leaves and stems at intervals by small brown discs of agglutinated hyphae, and hang in tangled masses between the branches (Plate 15, Fig. 4).

Because dead leaves and twigs are usually attached to the hair-like cords, the fungus is often mistaken to be a parasite, but careful observation shows that it gets its food only from the dead leaves and twigs in the tangle. When the opinion of parasitism is based on the appearance of the bush, and not on the fungus, it will be found that other less obvious fungi are doing the damage.

Horse-hair blight occurs in the Low-country, usually below 1,000 feet, in damp shady localities and is usually very evident shortly before the bushes are due for pruning. Other fungi, especially the parasite *Rhizoctonia solani,* flourish under the same conditions. The damage caused by *Rhizoctonia* is often attributed to Horse-hair blight because the latter fungus is obvious whereas the former is obscure and consequently overlooked.

The distribution of Horse-hair blight is effected by spores. If left on the ground, prunings from affected bushes produce fructifications in abundance. To prevent this prunings should be burnt, and any threads remaining in the bush should be brushed off the stems with a piece of coir.

Every year many tea bushes are killed by *Lightning* but the cause of their deaths is not always recognised. The mention of a tree being struck by lightning usually conjures up a mental picture of a "blasted oak" with stems split, branches torn off and the bark hanging in ribbons. Its effect on tea is very different. There are no scorched leaves and no split stems ; in fact there is no immediate visual injury though the bushes die later with all the symptoms of root disease.

Those at the strike-centre are the first to die, but the area of dead and dying bushes continues to increase for 2 or 3 weeks until, in some cases, more than 100 bushes are dead. This enlarging circle of dead bushes also gives the impression of a root disease at work, but the deaths occur far more rapidly than ever happens with any fungus root-disease of tea. When a shade tree is struck directly, there is an immediate visible effect of the lightning, yet when the tea bushes around it begin to die later, their deaths are sometimes wrongly attributed to a parasitic fungus emanating from the dead tree. Far more frequently there is no evidence of a direct

strike. The absence of sudden death, the time interval between the storm and the death of the bushes, and the frequency of thunderstorms are the main reasons why lightning damage is not immediately recognised as such. When a number of bushes die in quick succession in a patch, lightning should always be suspected.

The magnitude of the discharge, soil moisture and other physical conditions undoubtedly determine the extent of injury, the distance of lateral spread and the shape of the infected area. Little is known, however, concerning the way the electric discharge operates to cause death. The general symptoms suggest a serious interference with the water supply, probably by the destruction of the absorbing roots, but why there should be a relatively long interval between the discharge and the stoppage of water supplies is unknown.

One effect of the discharge can often be seen on large woody roots, before the bush dies. The cortex of the root appears healthy except for dark-brown narrow streaks and small circles with sharp boundaries, seen when the surface is scraped. The discoloration extends to the wood and sometimes into the wood for a depth of one or two millimetres. These injuries, of themselves, would not cause death, but they have been found only in bushes from lightning-struck areas.

Frost injury is rarely mistaken for anything else because the damage follows the frost so quickly. The frost-killed parts look as if scalded ; they lose their turgidity and the leaves rapidly turn brown and become dry.

At one time it was thought that the injury was due to the freezing water expanding and rupturing the cell walls. Microscopical observations, however, show that the cell walls remain uninjured, and that the ice is not formed within the cell but in the intercellular spaces. Frost killing is now regarded not as the direct influence of cold on the protoplasm but an indirect influence, the desiccation of protoplasm due to the withdrawal of water from the cell. It resembles the effect of drought.

Frosts occur in the tropics at night and they are succeeded by hot sunshine the following morning. This tends to increase the effect of the frost as water is evaporated from the leaves before the soil has warmed sufficiently to allow the roots to take up water quickly. They occur during clear cloudless nights and result from the loss of heat by radiation from the earth. Clouds reflect back

much of the radiated heat. For this reason the air is usually warmer during cloudy nights and frosts are less likely to occur then. As the earth cools rapidly the air above also becomes colder, denser and heavier. In consequence the cold air flows downwards to lower levels wherever there is an outlet. Thus the cold air on slopes slips down to the valley at a lower level where, if there is no escape, it accumulates and forms a frost pocket. The position of such frost pockets depends upon the contour of the surrounding land.

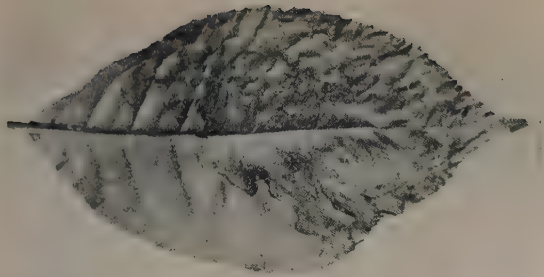
The principal means of reducing the injurious effect of transitory frosts is by decreasing radiation from the soil. The air is either heated directly by means of fires or portable stoves or a thick cloud of smoke is produced over the plants. These measures are useful in orchards but it is doubtful whether they would be economic in tea. Frost pockets should be avoided when siting tea nurseries.

Variegated leaves, green and yellow, are often seen on tea bushes (Plate 15, Fig. 2). The yellow colour is due to lack of chlorophyll though why it should not develop normally in particular zones is not known. An extreme case of chlorophyll absence has been observed in seedlings with entirely white leaves. Such plants do not survive. Plants with partially green leaves are able to elaborate sufficient food and many species are grown in gardens for their ornamental variegated leaves.

There are several types of variegation in tea. Two have been mentioned earlier. One occurs on branches invaded by the alga *Cephaleuros* and the other, observed once, is due to virus and is infectious. A third type is non-infectious and is probably the commonest. The boundaries between the green and yellow zones are sharp, in the other types the yellow merges gradually into the green. The non-infectious type of variegation occurs usually on single branches, not throughout the bush, but cuttings from such branches usually give rise to bushes with all leaves variegated. The condition, however, has not been transmitted to normal bushes and there is no evidence to suggest that it is ever infectious.

Galls and burrs are occasionally seen on tea bushes. Galls on roots caused by the root-knot eelworms and others, blister-like, on seedling leaves have already been mentioned. Others of various types are occasionally seen on stems, the largest measuring more than a foot in diameter. Little is known about the reason for their development and in no instance have they been found to be infectious.

PLATE 15.



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MISCELLANY.

1. Sun scorch on tea leaf. Note margin dividing healthy and scorched areas.
2. Variegated leaf (non-infectious.)
3. *Septobasium rimulosum* on tea stem.
4. Horse-hair blight.

When single node cuttings are planted, a small knob of callus forms at the lower end and from it arise the roots. That is normal development. The cuttings from some bushes form large knobs of callus without any roots developing from them, and when the callus is cut away, another, similar, forms. That is abnormal. This sort of cutting often forms a similar knob of callus at its upper end and that can only be regarded as abnormal healing. A few bushes have been found which produce similar knobs of callus at the ends of plucked shoots (Plate 14, Fig. 1) but in these cases the callus is woody. Also, similar outgrowths occur at unexpected places on the stems, often at the stem bases. A stem bearing a large number of small out growths is shown in Plate 14, (Fig. 2). Their origin was not determined but they are so numerous that it is very unlikely that each started from a wound.

In the normal process of healing of wounds a callus consisting of new wood and bark is produced at the edge of the wound. It continues to grow until the edges meet near the centre of the wound when they fuse and form a complete cover. In some instances instead of the callus-growths fusing, one passes over the other and continues to grow to form a thin plate often extending well beyond the wound.

The largest burrs are more or less hemispherical and may measure more than a foot in diameter. They project from one side of the stem and may almost completely encircle it. The surface is usually irregularly nodular (Plate 14, Fig. 3); their texture is woody with irregular grain and they frequently, if not invariably, originate at wounds.

In some respects perhaps these woody galls resemble cancer in animals, in that they are abnormal growths. Galls in some plants are known to be caused by bacteria and others by insects, but no such agent has been found associated with the galls on tea. All can be classed as abnormal callus growth but no reason can be given as to its cause.

LITERATURE

Gadd, C. H. Lightning. *Bull.* 8, 18 (1931). *Bull.* 26, 25-28, (1945).

— Sooty Mould. *Bull.* 18, 24-25 (1938).

— Horse-hair blight. *Bull.* 25, 25-26 (1944).

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